# GULF RESEARCH REPORTS

Vol. 6, No. 4
December 1980
ISSN: 0072–9027

*Published by the*
GULF COAST RESEARCH LABORATORY
Ocean Springs, Mississippi

## Gulf Research Reports

Volume 6 | Issue 4

January 1980

# Notes on the Northern Gulf of Mexico Occurrence of *Sagitta friderici* Ritter-Zahony (Chaetognatha)

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DOI: 10.18785/grr.0604.01

*Gulf Research Reports*, Vol. 6, No. 4, 343–348, 1980.

# NOTES ON THE NORTHERN GULF OF MEXICO OCCURRENCE OF *SAGITTA FRIDERICI* RITTER-ZAHONY (CHAETOGNATHA)

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*ABSTRACT* The neritic chaetognath *Sagitta friderici* Ritter-Zahony, 1911 was identified in plankton samples from the northern Gulf of Mexico in June 1974. Specimens analyzed from two groups of adults ranged from 6 to 13.7 mm long. Meristic values did not appear to be a function of body length except for individuals in the 12.4 to 13.7 mm range that had larger numbers of hooks and teeth.

Adults of *Sagitta friderici* and the closely related *S. tenuis* Conant, 1896 were compared and found to be distinguishable chiefly by (1) the number of ova per unit length of the ovary, and (2) the arrangement of ova within the ovary. The TC values were highly variable and overlapping, thus casting doubt on the taxonomic importance of that characteristic.

*Sagitta friderici* was abundant in inshore continental shelf waters where the salinity and temperature ranged from 24.9 to 33.9 ppt and 23.0 to 30.3°C, respectively. The failure to determine ecological boundaries between *S. friderici* and *S. tenuis* revealed a need for more intensive sampling in coastal regions of the Gulf of Mexico.

## INTRODUCTION

*Sagitta friderici* Ritter-Zahony, 1911 is generally described as a neritic, epiplanktonic chaetognath preferring lower salinity water near shore, but also able to tolerate oceanic salinities (Furnestin 1957, Colman 1959, Fraser 1961, Almeida-Prado 1968). Originally described from Cape Verde specimens by Ritter-Zahony (1910), it has been investigated extensively in the Mediterranean Sea and along the African and South American coasts in the Atlantic Ocean. Mattlin (1974) reported one juvenile specimen in the Caribbean Sea. Because Colman (1959) collected specimens of *S. friderici* over deep water in the eastern central Atlantic, a connecting bridge extending from east to west along the Guinea and Equatorial Currents in the South Atlantic was suggested by Vannucci and Hosoe (1952), Almeida-Prado (1961a), and Alvariño (1969).

In the eastern Pacific, *S. friderici* has been reported from the coast of Peru northward to the southern California coast of North America (Bieri 1957, 1959; Tokioka 1959, 1961). Confusion arose, however, with the descriptions of new, morphologically similar species, *S. euneritica* Alvariño from the California coast, and *S. peruviana* Sund and *S. popovicii* Sund from Peruvian waters (Alvariño 1961, Sund 1961). Tokioka (1961, 1965) did not accept the validity of these new species and maintained that *S. friderici* and *S. tenuis* Conant, 1896, being in the eastern Pacific, represented populations that immigrated from the Atlantic via a once-opened passage through Central America.

The only published record of *S. friderici* in the Gulf of Mexico is that of Laguarda-Figueras (1967) who studied the systematics and distribution of the species in the Laguna de Terminos (Campeche, Mexico). *Sagitta friderici* was the only chaetognath in two collections made in June 1965 and February 1966. Laguarda-Figueras' excellent descriptions and illustrations confirmed an earlier, tentative identification of the species by Suarez-Caabro and Gomez-Aguirre (1965) who investigated the Lagoon's zooplankton community.

*Sagitta friderici* has not been previously reported from the many plankton investigations along the Gulf and Atlantic coasts of the United States, presumably because of its confusion with the morphologically similar *S. tenuis*. Pierce (1951), in his pioneer work on the Chaetognatha of the west Florida coast, synonymized the two species because Ritter-Zahony's (1911) description of *S. friderici* was similar to the Florida specimens of *S. tenuis*. Tokioka (1955), on examining Pierce's specimens, concurred with their identification of *S. tenuis*, but also left open the possibility, as did Faure (1952) and Almeida-Prado (1961b) on reviewing Pierce's meristic data, that certain individuals might be immature specimens of *S. friderici*.

This paper discusses the occurrence of *S. friderici* in the northern Gulf of Mexico, and the methods currently used to separate the species from *S. tenuis*. This work is based, in part, on a thesis concerning the distribution of chaetognaths in the northeastern Gulf of Mexico (McLelland 1978).

## MATERIALS AND METHODS

Plankton samples and hydrographic data were collected in June 1974 by Gulf Coast Research Laboratory (GCRL) personnel as part of a U.S. Bureau of Land Management (BLM) baseline environmental survey of oil lease areas in the northeastern Gulf of Mexico, conducted by the State University System of Florida Institute of Oceanography Consortium (SUSIO/BLM Contract No. 08550–CT4–11, Final Report). Fifty-four zooplankton samples were examined from 12 stations over the continental shelf and slope with bottom depths ranging from 25 to 364 m (Figure 1). At each station the surface, mid-depth, and bottom strata were simultaneously sampled with Niskin 0.5 m, 202-mesh plankton nets equipped with double-trip, opening-and-closing devices and digital flowmeters. Samples were preserved in 5% buffered

Manuscript received July 24, 1980; accepted August 11, 1980.

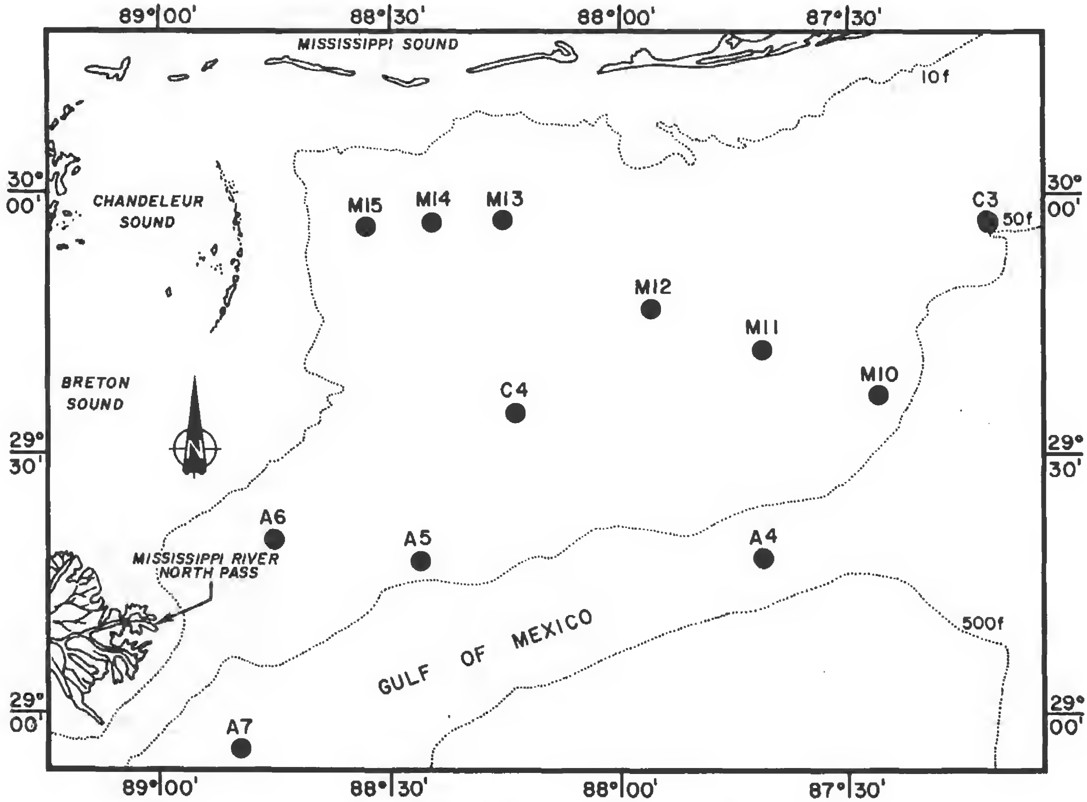


**Figure 1. Station locations in the northern Gulf of Mexico.**

formalin, aliquoted with a Folsom plankton splitter, and examined for chaetognaths under a stereoscopic dissecting microscope equipped with an ocular micrometer for measuring specimens.

Unstained specimens were examined under high magnification; dark-field illumination was occasionally used for better resolution of lateral and caudal fins. *Sagitta friderici* was identified with the aid of descriptions and illustrations from Faure (1952), Almeida-Prado (1961b), Alvariño (1969), and Laguarda-Figueras (1967).

Specimens of *S. friderici* and *S. tenuis* with fully developed ovaries were selected from preserved BLM samples for analysis of morphological features. Additional specimens of *S. friderici* were obtained from surface samples collected around the Mississippi River delta by Mr. John Steen (GCRL) aboard the NOAA R/V OREGON II on March 3, 1975.

## DESCRIPTION OF THE STUDY AREA

Stations were located along the continental slope east of the Mississippi River delta to a point south of Pensacola Bay, Florida, and on the continental shelf east of the Chandeleur Islands, Louisiana. Large environmental variations occur in this area from seasonal interactions of winds, tides, river discharges, and offshore currents (Drennan 1968). The Loop Current (see Figure 2), which enters the Gulf through the Yucatan Straits, is recognized as the main driving force for water circulation in the northeastern Gulf during the summer months (Eleuterius 1974). It is countered by eastward-flowing river water from eastern outlets of the Mississippi River, as well as low-salinity drainage from Mobile Bay, Alabama, and the island passes of Mississippi Sound. The resulting overlying, low-salinity water probably accounted for the presence of *S. friderici* at stations distant from the more neritic coastal waters.

## RESULTS AND DISCUSSION

*Description* (Figure 3)

Specimens of *Sagitta friderici* from the northeastern Gulf of Mexico have firm translucent bodies with all internal structures clearly visible. Intestinal diverticulae are absent. The collarette is well developed, and when retracted from the head, is distinguishable from the neck region posteriorly to a point about one third of the distance to the ventral

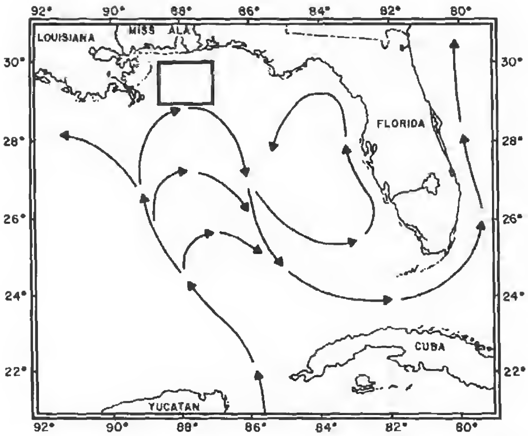


**Figure 2. The general path of the Loop Current in the eastern Gulf of Mexico during the summer months (after Leipper 1954). Box indicates study area.**

ganglion. The tapered anterior fins emerge at a point equal to the posterior edge of the ventral ganglion and extend posteriorly a length slightly less than that of the posterior fins. The rounded posterior fins are situated with more than half of their length on the caudal segment. Lateral and caudal fins are completely rayed. The seminal vesicles touch the edges of both the posterior and the caudal fins, and when mature, possess a characteristic circular process on the outer anterior portion of the cuticle. Tactile setae, or tangoreceptors, are numerous over the entire body cuticle; notable are a row of four prominent tufts located near the rear edge of the caudal fin and one near the outer edge of each posterior fin. The eyespots are square with one distal and two median clear spaces or "lenses."

Mature specimens varied in length from 6.0 to 9.7 mm in 19 specimens from the BLM samples, and 9.8 to 13.7 mm for 15 OREGON II specimens. The two groups of specimens were identical in all other respects. The taxonomic characters presented in Table 1 were not dependent on length except for three specimens in the 12.4- to 13.7-mm range that had larger numbers of hooks and teeth.

*Comparison with Sagitta tenuis*

Ovary characteristics are the chief distinguishing features between mature *S. friderici* and *S. tenuis*, a smaller chaetognath but similar in general appearance and morphometric description (Table 1). In *S. tenuis* (Figure 4a), the ovaries are usually confined to a length not reaching the anterior fin and contain ova that are larger and fewer in number than those of *S. friderici*. Mature ova of *S. tenuis* fill the space from intestine to body wall and are attached to the oviduct in single file; however, bunching may often affect their apparent alignment. Ovaries in *S. friderici* usually reach the midpoint of the anterior fin and contain numerous small ova in two or occasionally three rows (Figure 4b).

Ovary differences are illustrated by data presented in Table 2. *S. friderici*'s number of ova per ovary (28.2) nearly doubles the number of ova per millimeter (14.9) indicating the double-row arrangement of ova. A single row of ova is exhibited by *S. tenuis* with its nearly equal number of ova per millimeter (6.4) and ova per ovary (6.5). When these data are applied to the figures for percent of body length comprised by the ovaries, it can be seen that the ova of *S. tenuis*, though fewer in number, are larger in size. This analysis is further demonstrated in Figure 5 which shows for *S. friderici* a rapid increase in number of ova with increasing ovary length to a maximum of 43 ova for an ovary of 3 mm. The increase is more gradual in *S. tenuis*, with a maximum of 10 ova for an ovary of 1.8 mm.

Similar ovarian comparisons have been used by other authors to separate *S. tenuis* and *S. friderici*. Almeida-Prado (1961b), in an excellent account of the Brazilian chaetognaths, noted the size difference between the two species and concluded that the ovarian features of *S. tenuis* are "its principal differential character from *S. friderici*." Furnestin (1966) collected both species off the west coast of Africa and maintained that *S. tenuis*, though very close morphologically to *S. friderici*, can be distinguished by (1) smaller size of mature individuals (5 mm as compared to 8 to 13 mm for *S. friderici*), (2) longer ovaries that reach the middle of the anterior fin (a feature not observed in northeastern Gulf specimens), and (3) fewer ova

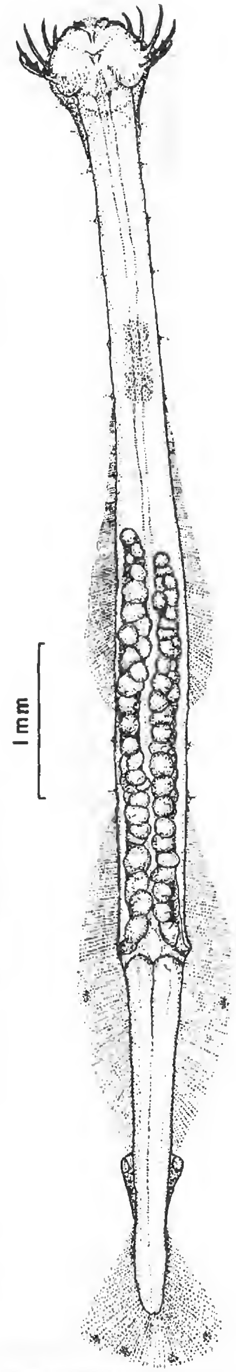


**Figure 3.** ***Sagitta friderici*** **Ritter-Zahony. Ventral view of whole animal.**

TABLE 1.

Comparative morphometric data for mature specimens of *Sagitta friderici* and *S. tenuis* collected in the northern Gulf of Mexico. Range means in paratheses.

| | Number of specimens | Length (mm) | Caudal segment percent of length | Number of hooks | Number of anterior teeth | Number of posterior teeth | TC* values |
|---|---|---|---|---|---|---|---|
| *S. friderici* | | | | | | | |
| | 5 | 6.0– 6.4 ( 6.2) | 25.8–30.0 (27.6) | 7 | 5–7 (6.0) | 14 | 55– 84 (73.8) |
| | 9 | 6.6– 6.9 ( 6.7) | 25.0–30.4 (28.0) | 7–8 (7.7) | 5–8 (5.9) | 13–17 (13.8) | 63– 94 (76.2) |
| | 4 | 7.1– 7.5 ( 7.2) | 26.7–29.2 (27.2) | 7–8 (7.5) | 6–8 (6.4) | 13–17 (14.9) | 61–100 (81.4) |
| | 4 | 7.6– 7.9 ( 7.8) | 25.0–30.4 (27.5) | 7–8 (7.5) | 6–8 (6.8) | 13–17 (14.5) | 71– 84 (77.0) |
| | 3 | 8.1– 8.5 ( 8.3) | 27.2–29.4 (28.8) | 7–8 (7.3) | 7 | 14–16 (15.3) | 56– 90 (73.3) |
| | 7 | 9.7–11.6 (10.9) | 25.7–30.2 (27.8) | 7–8 (7.7) | 6–8 (7.1) | 15–19 (17.0) | 60– 86 (73.4) |
| | 9 | 12.4–13.7 (12.9) | 27.8–29.8 (28.7) | 8–9 (8.2) | 7–9 (8.3) | 17–22 (18.7) | 70– 84 (76.1) |
| Totals and grand means | 41 | 6.0–13.7 ( 9.2) | 25.0–30.4 (28.0) | 7–9 (7.7) | 5–9 (6.9) | 13–22 (15.7) | 55–100 (76.0) |
| *S. tenuis* | | | | | | | |
| | 1 | 4.8 | 31.3 | 8 | 6 | 11 | 83 |
| | 4 | 5.5– 5.9 ( 5.7) | 24.6–32.2 (28.5) | 7–8 (7.3) | 5–6 (5.3) | 12–14 (13.0) | 62– 92 (70.7) |
| | 4 | 6.0– 6.3 ( 6.1) | 26.7–28.6 (27.8) | 7–8 (7.5) | 5–6 (5.3) | 10–14 (12.0) | 65– 89 (71.8) |
| Totals and grand means | 9 | 4.8– 6.3 ( 5.8) | 24.6–32.2 (28.5) | 7–8 (7.5) | 5–6 (5.4) | 10–14 (12.3) | 62– 92 (72.8) |

*TC = [(posterior fin length along trunk/posterior fin length along caudal segment) x 100]

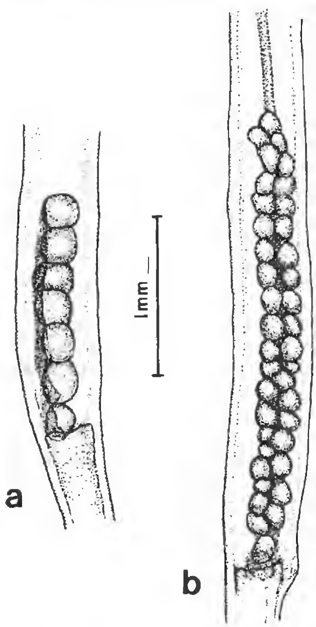


Figure 4. Comparative lateral views of ovaries. (a) *Sagitta tenuis*. (b) *S. friderici*.

(6 to 10 per ovary) which are larger in size, 0.13 to 1.80 mm.

Tokioka (1955, 1961) emphasized the "TC value" (see Table 1) as a means of separating the two species, with *S. friderici* having a substantially greater value than *S. tenuis*. However, Tokioka reported widely varying and often overlapping TC values in specimens he and other workers examined from several parts of the world. Grant (1963) also reported such an overlap when he compared TC values of his Virginia specimens of *S. tenuis* with those of *S. tenuis* from Florida, and *S. friderici* from Morocco as reported by Tokioka (1955). Likewise, no conclusive evidence of species separation was obtained when the TC method was applied to mature northeastern Gulf specimens (Table 1), because *S. tenuis* had values well within the range of *S. friderici*. Tokioka's method appears

TABLE 2.

Comparison of mean values of distinguishing characteristics between mature specimens of *Sagitta friderici* and *S. tenuis*.

| | *S. friderici* | *S. tenuis* |
|---|---|---|
| Number of specimens | 30 | 9 |
| Total length (mm) | 9.2 | 5.8 |
| Ovary length (mm) | 1.9 | 1.1 |
| Number of ova/ovary | 28.2 | 6.5 |
| Number of ova/mm ovary | 14.9 | 6.4 |
| [(ovary length/body length) x 100] | 21.2 | 19.0 |

to be dependent on well-preserved, undamaged specimens, conditions not usually found in the average plankton sample due to the delicate nature of the animals. Moreover, TC values probably vary among breeding populations in the same manner as numbers of hooks and teeth, and as such, should not be regarded as an important means of separating the two species.

*Distribution*

*Sagitta friderici* was the dominant chaetognath at the more landward BLM stations over the continental shelf, with a maximum of 40 individuals per m$^3$ at M13 (see Figure 1). It was also present in limited abundance in the upper water levels over the edge of the continental shelf. The majority of specimens were collected in the salinity range 24.9 to 33.9 ppt (80%), in the temperature range 23.0 to 30.3°C (93%), and in waters with oxygen content above 5.0 mg/l (99%). The species occurred predominantly in the epipelagic region

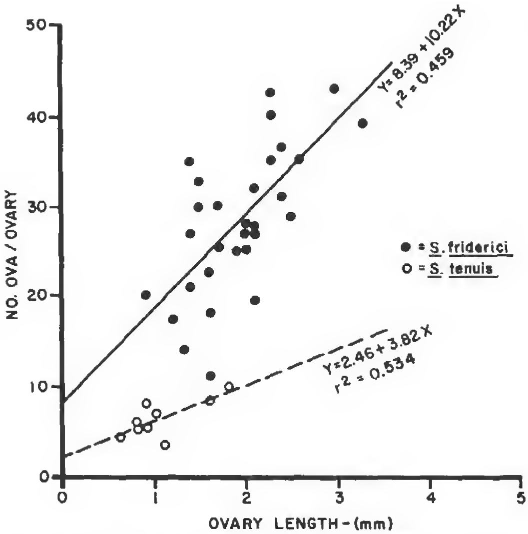


**Figure 5. Comparative relationships of number of ova per ovary to ovary length for *Sagitta friderici* and *S. tenuis*.**

(0 to 20 m); however, two specimens were present in a sample collected from 88 to 166 m at station A7.

*Sagitta friderici* probably occurs in less saline waters further inshore from the present study area; indeed, such salinity tolerance has been recorded in the literature. Laguarda-Figueras (1967) observed it in salinities as low as 14.0 ppt in the Laguna de Terminos. However, Fraser (1961) found *S. friderici* abundant along the coast of Nigeria in salinities between 11.5 and 12.0 ppt, and suggested that neither salinity nor temperature above 10°C influenced its distribution.

Some authors have commented on ecological barriers separating *S. friderici* and *S. tenuis.* According to Tokioka (1961), *S. tenuis* generally is found in protected embayments while *S. friderici* is confined to the more open neritic water mass. Furnestin (1966) reported a small population of *S. tenuis* near the mouth of the Congo River in salinities ranging from 22.0 to 24.0 ppt. She found this population to be equatorially centered along the western coast of Africa and generally separate from populations of *S. friderici* located in more saline waters to the north and south. In the northeastern Gulf, *S. friderici* and *S. tenuis* appeared to occupy basically the same habitat. Boundaries could not be determined between the two populations mainly because of the mixed surface waters characteristic of the region. Intensive monthly sampling in this and adjacent regions, both inshore and offshore, may provide a better definition of the population dynamics of these two neritic species in the northern Gulf of Mexico.

ACKNOWLEDGMENTS

The author is greatly indebted to Dr. Harding B. Michel of the University of Miami, who confirmed the identifications of *Sagitta friderici* and *S. tenuis.* Grateful appreciation is extended to Drs. Robert A. Woodmansee, Edwin W. Cake, Jr., Adrian R. Lawler, and Richard W. Heard, all of GCRL, for their time and effort in reviewing the manuscript, and also to Dr. Thomas L. Deardorff of GCRL for his advice concerning the illustrations.

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# Gulf Research Reports

Volume 6 | Issue 4

January 1980

A Partial Bibliography of *Cyprinodon variegatus* (Osteichthyes: Cyprinodontidae)

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DOI: 10.18785/grr.0604.02



Recommended Citation
Bengtson, D. A. 1980. A Partial Bibliography of *Cyprinodon variegatus* (Osteichthyes: Cyprinodontidae). Gulf Research Reports 6 (4): 349-357.
Retrieved from http://aquila.usm.edu/gcr/vol6/iss4/2

*Gulf Research Reports*, Vol. 6, No. 4, 349–357, 1980.

# A PARTIAL BIBLIOGRAPHY OF *CYPRINODON VARIEGATUS* (OSTEICHTHYES: CYPRINODONTIDAE)[1]

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*ABSTRACT* A partial bibliography of the sheepshead minnow *Cyprinodon variegatus* Lacépède, 1803, is presented. Scientific works related to systematics and general biology are listed along with references to recent work involving toxicological bioassays. An extensive search of the literature on parasites of *C. variegatus* was not conducted.

## INTRODUCTION

*Cyprinodon variegatus* is a relatively abundant inhabitant of estuarine marshes from Massachusetts to South America. Because of its importance in the estuarine ecosystem and the ease with which it can be cultured, it has become an increasingly important organism for toxicological bioassays.

Sheepshead minnows have a protracted spawning season and will breed year-round in warm water, with a generation time of three to four months. They feed on both algal and animal material in nature and can be easily reared on brine shrimp, *Artemia salina*, in aquaria.

Most 19th century references listed relate to systematics or collection records of *C. variegatus*. A great deal of work was done on the general biology and ecology of this species from 1900 to 1965. Over the past fifteen years, however, the majority of work has documented responses of *C. variegatus* to environmental pollutants. Thus, it is one of the few organisms for which we have a good biological data base as well as an assessment of man's potential impact on the estuarine environment.

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Manuscript received May 12, 1980; accepted July 11, 1980.

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# Gulf Research Reports

Volume 6 | Issue 4

January 1980

New Records of Hyperiidea (Crustacea: Amphipoda) from the North Central Gulf of Mexico

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DOI: 10.18785/grr.0604.03

*Gulf Research Reports*, Vol. 6, No. 4, 359–370, 1980.

# NEW RECORDS OF HYPERIIDEA (CRUSTACEA: AMPHIPODA) FROM THE NORTH CENTRAL GULF OF MEXICO[1]

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*ABSTRACT* Records of 54 species of amphipods of the suborder Hyperiidea from the Gulf of Mexico are presented. Forty-seven species are recorded from the Gulf for the first time. Previous records of occurrence in the Gulf of Mexico, Caribbean Sea, and associated North Atlantic waters are provided for each species.

## INTRODUCTION

Few of the major oceanographic expeditions of the late nineteenth and early twentieth centuries ventured into the Caribbean Sea and Gulf of Mexico region. Of the limited investigations of Gulf plankton, few have dealt in detail with the pelagic amphipods. As a result, the hyperiid amphipod fauna of the Gulf of Mexico are poorly known.

Pearse (1913) recorded three species of hyperiid amphipods, *Cystisoma spinosum, Phronima sedentaria* and *Phrosina semilunata*, from northern Gulf waters. Springer and Bullis (1956) and Bullis and Thompson (1965) reported eight hyperiid species from the Gulf of Mexico cruises of the R/V OREGON II: *Scina crassicornis, Phronima sedentaria, Phrosina semilunata, Parapronoe crustulum, Platyscelus ovoides, Oxycephalus clausi, Sympronoe parva*, and *Hemityphis rapax*. Hopkins (1966) recorded two hyperiid amphipods, *Hyperia atlantica* (syn. *Lestrigonus bengalensis*) and *Simorhynchotus antennarius*, from the St. Andrew Bay system, Florida. Gillespie (1971) reported *Hyperia atlantica, Phronima* sp., and *Primno* sp. from coastal waters of southern Louisiana. The Dana expedition of 1921-22 occupied a limited number of stations in the eastern Gulf, from which records of *Phronima sedentaria* and *Phronima pacifica* were established (Shih 1969).

The hyperiid fauna of the neighboring Caribbean Sea and western North Atlantic have received attention in several studies. Moryakova (1968), Madin and Harbison (1977), and Harbison et al. (1977) listed numerous hyperiids associated with gelatinous zooplankton. Seventeen species of hyperiids were reported from Caribbean waters near Barbados (Lewis and Fish 1969, Moore and Sander 1977), and Moore and Sander (1979) listed three species from waters near Jamaica. Shoemaker (1948) identified eight species of hyperiids from the southwestern coast of Cuba. Hyperiid amphipods of the subgenus *Parahyperia*, occurring in the Florida Current, were reviewed by Yang (1960). Bovallius (1887, 1889, 1890) listed several species of Hyperiidea from the Caribbean Sea and from the tropical waters of the Atlantic Ocean. The Dana expeditions of 1920-22 occupied several stations in the Caribbean Sea, Florida Straits, and associated western North Atlantic waters. Hyperiid amphipods of the families Oxycephalidae and Phronimidae from these cruises were studied by Fage (1960) and Shih (1969), respectively. The hyperiid fauna of the tropical and warm temperate waters of the western North Atlantic have been discussed by Vosseler (1901), Shoemaker (1945), Evans (1961), and Grice and Hart (1962).

This report is intended to establish new and supplemental records of hyperiid amphipods of the Gulf of Mexico. A comprehensive key to the hyperiids of the Caribbean Sea-Gulf of Mexico region will be presented at a later date.

## MATERIALS AND METHODS

This report is based in large part on a master's thesis presented by the senior author to the University of Southern Mississippi. Specimens were provided to the authors from the following sources:

1. National Marine Fisheries Service under Public Law 88–309, Project 2–42–R.
2. National Marine Fisheries Service under Public Law 88–309, Project 2–215–R.
3. Shiao Wang, personal collection of specimens from stations 11 and 12.

Collection sites (Figure 1), gear types, and water depths are listed in Table 1.

Selected synonymies of interest to local investigators are provided. Detailed synonymies can be found in the listed reference of latest date. Records of occurrence follow the style of Stuck et al. (1979). Stations are designated as day (D) or night (N), and are followed by the depth of tow (S—surface, M—midwater, B—bottom). The number of specimens listed in materials examined represents a small fraction of a large collection of pelagic amphipods (over 6,000 specimens) examined by the senior author. Figures within the parentheses represent the number of males, females, ovigerous females, and immature specimens (0–0–0–0). A brief summary of world distribution is presented for each species. Records from the tropical and warm temperate waters (below 40°N latitude) of the western North Atlantic, Caribbean Sea, and Gulf of Mexico are given.

A representative collection of the hyperiid amphipods reported in this paper has been deposited in the U.S. National Museum of Natural History, Washington, D.C.

[1]This work was conducted in cooperation with the Department of Commerce, NOAA, National Marine Fisheries Service, under Public Law 88–309, Projects 2–42–R and 2–215–R.

Manuscript received Sept. 9, 1980; accepted Sept. 29, 1980.

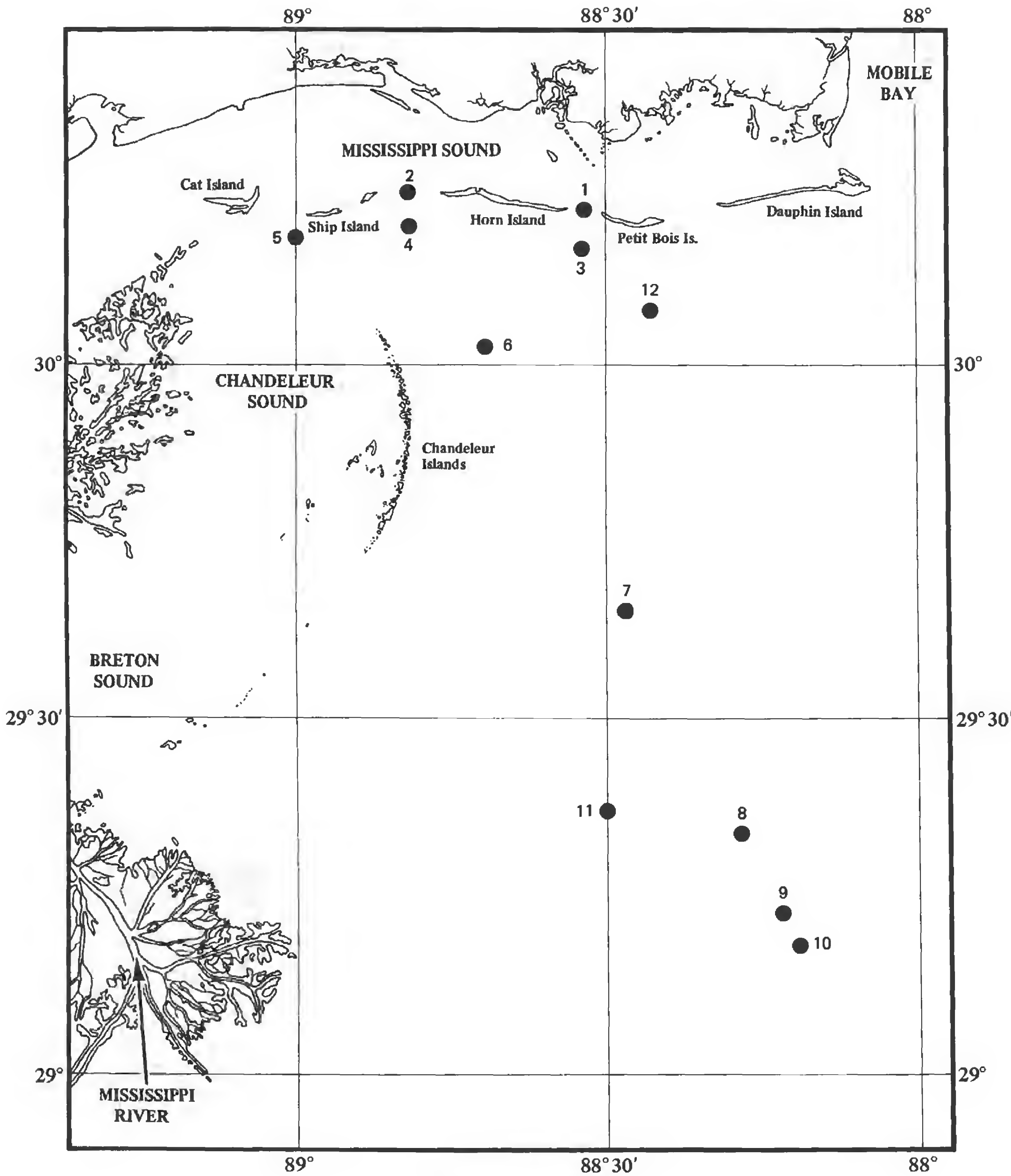


Figure 1. Station locations.

**TABLE 1.**

**Station locations, gear types, and water depth.**

| Station Number | Station Location | Gear Type | Water Depth (m) |
|---|---|---|---|
| 1 | Horn Island Pass, Mississippi | Clarke-Bumpus plankton sampler | 13 |
| 2 | Dog Keys Pass, Mississippi | Clarke-Bumpus plankton sampler | 10 |
| 3 | 30°09.5′ N latitude, 88°31.0′ W longitude | Meter Nekton net | 11 |
| 4 | 30°11.2′ N latitude, 88°47.0′ W longitude | Meter Nekton net | 11 |
| 5 | 30°09.5′ N latitude, 88°59.5′ W longitude | Meter Nekton net | 8 |
| 6 | 30°02.5′ N latitude, 88°40.2′ W longitude | 0.5 meter plankton net | 18 |
| 7 | 29°42.0′ N latitude, 88°27.5′ W longitude | 0.5 meter plankton net | 37 |
| 8 | 29°24.4′ N latitude, 88°17.0′ W longitude | 0.5 meter plankton net | 55 |
| 9 | 29°19.0′ N latitude, 88°14.0′ W longitude | 0.5 meter plankton net | 73 |
| 10 | 29°17.2′ N latitude, 88°12.1′ W longitude | 0.5 meter plankton net | 91 |
| 11 | 29°25.0′ N latitude, 88°30.0′ W longitude | 0.5 meter plankton net | 31 |
| 12 | 30°05.0′ N latitude, 88°20.0′ W longitude | 0.5 meter plankton net | 20 |

## SPECIES ACCOUNT

### Family Scinidae

#### *Scina tullbergi* (Bovallius)

*Tyro tullbergi* Bovallius, 1885, p. 15
*Scina concors:* Stebbing, 1895, p. 360, pl. 53B
*Scina tullbergi:* Wagler, 1926, p. 384, figs. 34–35
*Scina tullbergi:* Shoemaker, 1945, p. 232

*Material Examined* – 8NB (0–1–0–0).

*Distribution* – Widely distributed in warm waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Dick 1970). Reported from the western North Atlantic near Bermuda (Shoemaker 1945). This is the first record for the Caribbean Sea-Gulf of Mexico region.

### Family Vibiliidae

#### *Vibilia australis* Stebbing

*Vibilia australis* Stebbing, 1888, p. 1287, pl. 149
*Vibilia australis:* Behning 1925, p. 488, figs. 32–34
*Vibilia australis:* Barnard, 1932, p. 264

*Material Examined* – 7NM (0–1–0–0).

*Distribution* – Indian Ocean, Red Sea, South Pacific, and Equatorial Atlantic (Reid 1955). The present record is the first for the Caribbean Sea-Gulf of Mexico region.

### Family Paraphronimidae

#### *Paraphronima crassipes* Claus

*Paraphronima crassipes* Claus, 1879b, p. 65, pl. 1, figs. 6–9, pl. 2, fig. 10
*Paraphronima crassipes:* Bovallius, 1889, p. 30, pl. 2, figs. 11–15
*Paraphronima clypeata:* Bovallius, 1889, p. 33, pl. 2, figs. 16–40
*Paraphronima crassipes:* Chevreux and Fage, 1925, p. 390, figs. 393–394
*Paraphronima crassipes:* Shoemaker, 1945, p. 234

*Material Examined* – 3DS (0–1–0–0), 10NS (0–1–0–0).

*Distribution* – Widely distributed in warm waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Dick 1970). Recorded from the tropical western North Atlantic (Vosseler 1901), and Bermuda (Shoemaker 1945). Reported from the Caribbean Sea (Bovallius 1889), and the north central Gulf of Mexico (present study).

#### *Paraphronima gracilis* Claus

*Paraphronima gracilis* Claus, 1879b, p. 65, pl. 1, figs. 4–5
*Paraphronima cuivis:* Stebbing, 1888, p. 1337, pl. 157
*Paraphronima gracilis:* Bovallius, 1889, p. 27, pl. 2, figs. 1–10
*Paraphronima gracilis:* Chevreux and Fage, 1925, p. 391, fig. 394 (in part)
*Paraphronima gracilis:* Spandl, 1927, p. 165, fig. 6

*Material Examined* – 1NS (1–1–0–0).

*Distribution* – Widely distributed in warm waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Dick 1970). Reported from the tropical western North Atlantic (Vosseler 1901, Evans 1961), between New York and Bermuda (Grice and Hart 1962), the Caribbean Sea near Barbados (Lewis and Fish 1969), and the northern Gulf of Mexico (present study).

### Family Hyperiidae

#### *Hyperietta vosseleri* (Stebbing)

*Hyperia vosseleri* Stebbing, 1904, p. 34
*Hyperia fabrei:* Yang, 1960, p. 33, fig. 8
*Hyperietta vosseleri:* Bowman, 1973, p. 58, figs. 41–42

*Material Examined* – 3NB (0–1–0–0), 3DS (1–0–0–0), 6NB (1–2–0–1), 7DM (0–1–0–0), 8DM (2–6–2–1), 9DS (1–4–1–5), 10DM (0–2–1–1), 11 DS (0–1–1–0).

*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans (Bowman 1973). Wide distribution in the western North Atlantic (Vosseler 1901, Grice and Hart 1962). Reported from the Caribbean Sea near Barbados (Lewis and Fish 1969, Moore and Sander 1977), the Florida Current (Yang 1960), and the north central Gulf of Mexico (present study).

#### *Hyperietta luzoni* (Stebbing)

*Hyperia luzoni* Stebbing, 1888, p. 1382, pl. 166A
*Hyperietta luzoni:* Bowman, 1973, p. 55, figs. 39–40

*Material Examined* – 9DS (0–1–0–1).

*Distribution* – Warm waters of the Pacific Ocean (Bowman 1973), the Mediterranean Sea, and eastern North Altantic (Stephensen 1924). Reported from the western North Atlantic waters between New York and Bermuda (Grice and Hart 1962). This is the first record of this species from the Caribbean Sea-Gulf of Mexico region.

#### *Hyperietta stebbingi* Bowman

*Hyperia luzoni:* Vosseler, 1901, p. 64, pl. 5, figs. 16–28
*Hyperietta stebbingi* Bowman, 1973, p. 61, figs. 43–45

*Material Examined* – 10NS (3–0–0–0).

*Distribution* – Warm waters of the Pacific, Indian, and Atlantic oceans (Bowman 1973). Reported from the warm waters of the western North Atlantic (Vosseler 1901, Harbison et al. 1977). This is the first record of this species from the Caribbean Sea-Gulf of Mexico region.

#### *Hyperietta stephenseni* Bowman

*Hyperietta stephenseni* Bowman, 1973, p. 61, figs. 46–48

*Material Examined* – 8DB (2–2–0–0), 8NS (0–1–0–0), 9DM (1–0–0–0).

*Distribution* – Warmer parts of the Atlantic, Pacific, and Indian oceans (Bowman 1973). This is the first record of this species from the Caribbean Sea-Gulf of Mexico region.

#### *Lestrigonus bengalensis* Giles

*Lestrigonus bengalensis* Giles, 1887, p. 224, pls. 6–7
*Hyperia bengalensis:* Bovallius, 1889, p. 199
*Hyperia thoracica:* Bovallius, 1889, p. 233, pl. 11, figs. 37–41
*Hyperia atlantica:* Vosseler, 1901, p. 67, pl. 6, figs. 5–15
*Lestrigonus bengalensis:* Bowman, 1973, p. 50, figs. 37–38

*Material Examined* – 1DS (1–2–1–0), 2DS (4–2–1–2), 2DB (3–2–1–1), 3DS (10–26–2–5), 3DB (6–11–0–2), 4DS (11–21–1–2), 4DB (6–6–0–1), 5DS (2–5–0–1), 5DB (0–3–0–1), 6DB (1–2–1–1), 6NM (1–3–2–0), 7NS (2–9–1–1), 7NB (1–2–0–1), 8NS (10–12–1–6), 8DS (2–6–0–0), 9DM (6–17–2–3), 9NM (6–2–0–0), 10DB (2–7–1–1), 10NS (3–1–0–1), 11DS (4–11–11–6), 12 DS (6–42–7–5).

*Distribution* – Worldwide in tropical waters (Bowman 1973). Reported from warm waters of the western North Atlantic (Vosseler 1901, Grice and Hart 1962, Harbison et al. 1977), the Caribbean Sea near Barbados (Lewis and Fish 1969, Moore and Sander 1977), Jamaica (Moore and Sander 1979), the Florida Current (Yang 1960), and the northern Gulf of Mexico (Hopkins 1966, Gillespie 1971).

*Remarks* – *Lestrigonus bengalensis* is the most common hyperiid amphipod found in the coastal waters of the northern Gulf. It was present in all offshore samples examined and commonly occurred in nearshore waters.

#### *Lestrigonus schizogeneios* (Stebbing)

*Hyperia schizogeneios* Stebbing, 1888, p. 1391, pl. 168
*Hyperia promontorii:* Stebbing, 1888, p. 1385, pl. 166B
*Hyperia schizogeneios:* Yang, 1960, p. 15, figs. 1–3
*Lestrigonus schizogeneios:* Bowman, 1973, p. 39, figs. 28–30

*Material Examined*– 3DB (1–2–0–0), 4DS (1–3–0–0), 7NS (0–2–0–1), 8DB (1–2–0–0), 9DS (1–1–0–0), 10NM (1–3–1–0), 11DS (0–1–0–0).

*Distribution* – Warm water areas around the world (Bowman 1973). Reported from the western North Atlantic (Vosseler 1901, Evans 1961, Harbison et al. 1977), the east and central Caribbean Sea (Moryakova 1968), the Florida Current (Yang 1960), and the north central Gulf of Mexico (present study).

#### *Lestrigonus crucipes* (Bovallius)

*Hyperia crucipes* Bovallius, 1889, p. 225, pl. 11, figs. 14–25
*Lestrigonus crucipes:* Bowman, 1973, p. 43, fig. 31

*Material Examined* – 5NM (0–1–0–0), 10 NM (1–2–0–0).

*Distribution* – Warm water areas of the Indian and Atlantic oceans (Bowman 1973). Reported from the western North Atlantic (Harbison et al. 1977), and the north central Gulf of Mexico (present study).

#### *Lestrigonus macrophthalmus* (Vosseler)

*Hyperia macrophthalma* Vosseler, 1901, p. 70, pl. 6, figs. 16–25
*Hyperia macrophthalma:* Yang, 1960, p. 19, figs. 4–5
*Lestrigonus macrophthalmus:* Bowman, 1973, p. 48, fig. 35

*Material Examined* – 4DS (1–0–0–0), 4DB (0–1–0–0), 7NM (1–2–0–0), 9DS (0–1–0–0), 10DM (1–2–0–1), 10DB (2–1–0–0), 12 DS (3–1–1–5).

*Distribution* – Tropical parts of the Atlantic, Pacific, and Indian oceans (Bowman 1973). Reported from western North Atlantic between New York and Bermuda (Grice and Hart 1962), the Caribbean Sea near Barbados (Lewis and Fish 1969, Moore and Sander 1977), the Florida Current (Yang 1960), and the north central Gulf of Mexico (present study).

#### *Lestrigonus latissimus* (Bovallius)

*Hyperia latissima* Bovallius, 1889, p. 229, pl. 11, figs. 26–36
*Hyperia hydrocephala:* Vosseler, 1901, p. 74, pl. 6, figs. 26–28, pl. 7, figs. 1–5
*Hyperia bengalensis:* Shoemaker, 1945, p. 238
*Hyperia bengalensis:* Shoemaker, 1948, p. 12
*Lestrigonus latissimus:* Bowman, 1973, p. 50, fig. 36

*Material Examined* – 3DS (0–1–0–0), 6NB (1–2–0–0), 7NM (1–1–0–1), 8DB (2–1–1–0), 9NM (1–2–0–1), 10DM (1–0–0–0), 10NM (2–3–0–0).

*Distribution* – Mediterranean Sea, eastern Atlantic (Bowman 1973). Reported from the western North Atlantic (Vosseler 1901), near Bermuda (Shoemaker 1945), Bahia Corrientes on the southwestern coast of Cuba (Shoemaker 1948), and the northern Gulf of Mexico (present study).

#### *Hyperioides longipes* Chevreux

*Hyperioides longipes* Chevreux, 1900, p. 143, pl. 17, fig. 2
*Hyperia sibaginis:* Vosseler, 1901, p. 60, pl. 7, figs. 6–20
*Hyperioides longipes:* Bowman, 1973, p. 33, figs. 24–25

*Material Examined* – 10NB (1–2–0–0), 10DB (0–2–0–0).

*Distribution* – Known from warm waters of all the world oceans (Bowman 1973). Wide distribution in the western North Atlantic (Vosseler 1901). Recorded from Bermuda (Shoemaker 1945), the Caribbean Sea near Barbados (Lewis and Fish 1969, Moore and Sander 1977), and the north central Gulf of Mexico (present study).

#### *Themistella fusca* (Dana)

*Lestrigonus fuscus* Dana, 1853, p. 983, pl. 67, figs. 8a–c
*Hyperia thoracica:* Vosseler, 1901, p. 73, pl. 6, figs. 1–4
*Themistella fusca:* Bowman, 1973, p. 66, fig. 51

*Material Examined* – 1DS (3–0–0–0), 3DB (3–7–0–0), 3DS (2–2–0–0), 4DS (1–3–0–0), 5DS (0–1–0–0), 6NB (2–3–0–1), 7NM (2–2–0–1), 8NS (1–1–0–0), 10NM (0–2–0–0), 12DS (0–3–0–2).

*Distribution* – Worldwide in tropical waters (Bowman 1973). Reported from the tropical western North Atlantic (Vosseler 1901), the Caribbean Sea off Barbados (Bowman 1973), and the north central Gulf of Mexico (present study).

#### *Phronimopsis spinifera* Claus

*Phronimopsis spinifer* Claus, 1879b, p. 64, pl. 1, figs. 1–3
*Phronimopsis sarsii:* Bovallius, 1889, p. 320, pl. 14, figs. 1–29
*Phronimopsis spinifera:* Chevreux and Fage, 1925, p. 408, fig. 406
*Phronimopsis spinifera:* Shoemaker, 1945, p. 242

*Material Examined* – 8NS (1–2–0–0), 9DM (2–3–0–1).

*Distribution* – Tropical and temperate areas of the Indian, Pacific, and Atlantic oceans, and the Red and Mediterranean seas (Dick 1970). Reported from the western North Atlantic near Bermuda (Shoemaker 1945), the Caribbean Sea (Bovallius 1889), and the north central Gulf of Mexico (present study).

#### *Hyperionyx macrodactylus* (Stephensen)

*Hyperia macrodactyla* Stephensen, 1924, p. 90, fig. 35
*Hyperia (Parahyperia) macrodactyla:* Yang, 1960, p. 35, fig. 9
*Hyperionyx macrodactylus:* Bowman, 1973, p. 71, fig. 52

*Material Examined* – 7NM (1–3–0–1).

*Distribution* – Pacific Ocean near the Fiji Islands (Hurley 1960), the South Atlantic Ocean (Dick 1970), and the Mediterranean Sea (Stephensen 1924). Reported from the Florida Current off Miami (Yang 1960), and the north central Gulf of Mexico (present study).

### Family Dairellidae

#### *Dairella latissima* Bovallius

*Dairella latissima* Bovallius, 1887, p. 24
*Dairella bovallii:* Stebbing, 1888, p. 1343, pl. 158
*Dairella latissima:* Bovallius, 1889, p. 336, pl. 15, figs. 1–20
*Dairella latissima:* Barnard, 1932, p. 282

*Material Examined* – 12DS (1–0–0–0).

*Distribution* – Warm water regions of the Atlantic and Indian oceans, and the Mediterranean Sea (Dick 1970). Reported from the western North Atlantic waters between New York and Bermuda (Grice and Hart 1962), and the north central Gulf of Mexico (present study).

### Family Phronimidae

#### *Phronimella elongata* (Claus)

*Phronima elongata* Claus, 1862, p. 193, pl. 19, figs. 2, 3, 7
*Phronimella elongata:* Stebbing, 1888, p. 1362, pl. 163
*Phronimella elongata:* Shih, 1969, p. 30, figs. 8, 21

*Material Examined* – 8NS (0–1–0–0), 9NM (0–1–0–0), 9NS (1–0–0–0).

*Distribution* – Widely distributed in the warm water regions of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Shih 1969). Reported from the western North Atlantic (Vosseler 1901, Evans 1961, Shih 1969, Harbison et al. 1977), near Bermuda (Shoemaker 1945), the Caribbean waters near Barbados (Shih 1969), and the north central Gulf of Mexico (present study).

#### *Phronima atlantica* Guérin

*Phronima atlantica* Guérin, 1836, p. 7, pl. 18, fig. 1
*Phronima atlantica:* Bovallius, 1889, p. 374, pl. 16, figs. 19–26
*Phronima atlantica:* Shih, 1969, p. 14, figs. 2, 15

*Material Examined* – 1DS (0–1–0–0), 10DM (0–1–0–0).

*Distribution* – Widely distributed in warm waters of the Atlantic, Pacific and Indian oceans, and the Mediterranean and Red seas (Shih 1969). Reported from the western North Atlantic (Vosseler 1901, Shih 1969, Harbison et al. 1977), near Bermuda (Shoemaker 1945), the Caribbean waters near Barbados (Lewis and Fish 1969, Shih 1969, Moore and Sander 1977), and the north central Gulf of Mexico (present study).

#### *Phronima pacifica* Streets

*Phronima pacifica* Streets, 1877, p. 128
*Phronima pacifica:* Vosseler, 1901, p. 29, pl. 3, figs. 4–7
*Phronima pacifica:* Shih, 1969, p. 18, figs. 4, 17

*Material Examined* – 1NS (1–1–0–0), 3DS (0–1–0–0), 4DS (0–1–0–0), 9NM (0–1–0–0), 10DM (0–1–0–0).

*Distribution* – Widely distributed in the warm waters of the Atlantic; also noted in the Pacific and Indian oceans, and the Mediterranean Sea (Shih 1969). Reported from northern Atlantic waters near Bermuda (Shoemaker 1945), the Caribbean Sea and Yucatan Channel (Shih 1969), and the north central Gulf of Mexico (present study).

#### *Phronima soiltaria* Guérin

*Phronima solitaria* Guérin, 1836, p. 7, pl. 18, fig. 1
*Phronima atlantica* var. *solitaria:* Vosseler, 1901, p. 23, pl. 2, fig. 5
*Phronima solitaria:* Shih, 1969, p. 16, figs. 3, 16

*Material Examined* – 3DS (0–1–0–0), 4DS (0–0–0–0).

*Distribution* – Warm waters of the Atlantic, eastern Pacific, and Indian oceans, and the Mediterranean and Red seas (Shih 1969). Reported from the western North Atlantic (Shoemaker 1945, Shih 1969, Harbison et al. 1977), the Florida Straits (Shih 1969), and the north central Gulf of Mexico (present study).

#### *Phronima stebbingi* Vosseler

*Phronima stebbingii* Vosseler, 1900, p. 402
*Phronima stebbingii:* Vosseler, 1901, p. 36, pl. 4, figs. 4–10
*Phronima stebbingi:* Shih, 1969, p. 29, figs. 7, 20

*Material Examined* – 7NM (0–1–0–0).

*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Shih 1969). Wide distribution in the western North Atlantic (Vosseler 1901, Shoemaker 1945, Evans 1961, Grice and Hart 1962). Reported from the Caribbean Sea at Mona Passage (Shih 1969), and the north central Gulf of Mexico (present study).

### Family Phrosinidae

#### *Phrosina semilunata* Risso

*Phrosina semilunata* Risso, 1822, p. 245
*Phrosina semilunata:* Chevreux and Fage, 1925, p. 413, fig. 409
*Phrosina semilunata:* Pillai, 1966b, p. 219, fig. 11

*Material Examined* – 1DS (0–1–0–0), 3DS (2–11–0–0), 6NM (1–4–0–2), 7NM (3–8–1–2), 8DB (0–2–0–0), 9NM (1–6–0–1), 9DM (0–3–0–0), 10NM (1–4–0–2), 10DB (1–6–0–1).

*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Shoemaker 1945). Wide distribution in the western North Atlantic (Vosseler 1901, Evans 1961, Grice and Hart 1962, Harbison et al. 1977), near Bermuda (Shoemaker 1945), the Caribbean Sea near Barbados (Lewis and Fish 1969, Moore and Sander 1977), and the Gulf of Mexico (Pearse 1913, Springer and Bullis 1956, Bullis and Thompson 1965).

#### *Anchylomera blossevillii* Milne-Edwards

*Anchylomera blossevillii* Milne-Edwards, 1830, p. 394
*Anchylomera blossevillei:* Chevreux and Fage, 1925, p. 414, fig. 410
*Anchylomera blossevillei:* Pillai, 1966b, p. 218, fig. 10

*Material Examined* – 7NM (0–2–0–1), 9DM (1–2–0–0), 11DS (0–1–0–0), 12DS (0–2–0–1).

*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean and Red seas (Dick 1970). Wide distribution in the western North Atlantic (Vosseler 1901, Evans 1961, Grice and Hart 1962). Also reported from Bermuda (Shoemaker 1945), the Caribbean Sea near Barbados (Lewis and Fish 1969, Moore and Sander 1977), and the north central Gulf of Mexico (present study).

#### *Primno brevidens* Bowman

*Primno macropa:* Stebbing, 1888, p. 1441, pl. 178
*Primno brevidens* Bowman, 1978, p. 8, figs. 3d–j, 5–8

*Material Examined* – 4DS (0–2–0–0), 7NM (0–2–0–1), 8DB (1–3–2–4), 9DM (0–3–0–1).

*Distribution* – Pacific Ocean and southeastern Gulf of Guinea (Bowman 1978). This is the first record of this species from the Caribbean Sea-Gulf of Mexico region.

*Remarks* – The genus *Primno* was revised by Bowman in 1978. Prior to that revision, records of several species of *Primno* were included under a single species *Primno macropa;* consequently, the distribution of this genus is poorly understood.

#### *Primno johnsoni* Bowman

*Euprimno macropus:* Chevreux and Fage, 1925, p. 416, fig. 411
*Primno macropa:* Shoemaker, 1945, p. 234
*Primno johnsoni* Bowman, 1978, p. 15, figs. 11–13

*Material Examined* – 3DS (0–1–0–0), 3DB (1–0–0–0),

4DB (1–4–0–0), 7NM (1–3–0–0), 8DM (1–2–0–0), 9NM (0–3–0–2), 10DM (1–4–0–6).

*Distribution* – South Pacific Ocean and the north Atlantic Ocean near the Canary Islands (Bowman 1978). Reported from the western North Atlantic near Bermuda (Shoemaker 1945), and the north central Gulf of Mexico (present study).

*Remarks* – See "Remarks" *Primno brevidens.*

### Family Lycaeopsidae

#### *Lycaeopsis themistoides* Claus

*Lycaeopsis themistoides* Claus, 1879a, p. 188(42)
*Lycaeopsis themistoides:* Chevreux and Fage, 1925, p. 417, fig. 412
*Lycaeopsis themistoides:* Spandl, 1927, p. 213, fig. 35
*Lycaeopsis themistoides:* Pirlot, 1930, p. 27, fig. 8

*Material Examined* – 9DM (0–2–0–0).

*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean and Red seas (Dick 1970). Reported from the tropical western North Atlantic (Evans 1961, Harbison et al. 1977), between Bermuda and New York (Grice and Hart 1962), and the north central Gulf of Mexico (present study).

*Remarks* – The genus *Lycaeopsis* is in need of revision and identification of species is tentative (Bowman, personal communication).

#### *Lycaeopsis zamboangae* (Stebbing)

*Phorcorrhaphis zamboangae* Stebbing, 1888, p. 1452, pl. 180
*Lycaeopsis zamboangae:* Pirlot, 1930, p. 28, fig. 9
*Lycaeopsis zamboangae:* Pillai, 1966b, p. 222, figs. 13, 13a

*Material Examined* – 4DB (1–1–0–0).

*Distribution* – Warm waters of the Atlantic and Pacific oceans, and the Red Sea (Dick 1970). The present record is the first for the Caribbean Sea-Gulf of Mexico region.

*Remarks* – See "Remarks" *Lycaeopsis themistoides.*

### Family Pronoidae

#### *Eupronoe armata* Claus

*Eupronoe armata* Claus, 1879a, p. 174(28)
*Eupronoe intermedia:* Stebbing, 1888, p. 1517, pl. 188
*Eupronoe armata:* Pillai, 1966b, p. 220, fig. 12

*Material Examined* – 2DS (0–1–0–0), 3DB (6–1–0–0), 4DB (0–2–0–0), 6DB (1–2–0–0), 10DM (0–2–0–1), 12DS (0–3–0–0).

*Distribution* – Warm waters of the Atlantic and Indian oceans (Dick 1970). Reported from the tropical western North Atlantic (Evans 1961). The present records are the first for the Caribbean Sea-Gulf of Mexico region.

#### *Eupronoe minuta* Claus

*Eupronoe minuta* Claus, 1879a, p. 174(28)
*Eupronoe minuta:* Claus, 1887, p. 53, pl. 14, figs. 7–12
*Eupronoe minuta:* Chevreux and Fage, 1925, p. 425, fig. 417
*Eupronoe minuta:* Shoemaker, 1945, p. 245

*Material Examined* – 6DB (2–0–0–0), 10NB (0–2–0–0).

*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Dick 1970). Reported from the western North Atlantic near Bermuda (Shoemaker 1945). The present records are the first for the Caribbean Sea-Gulf of Mexico region.

#### *Paralycaea gracilis* Claus

*Paralycaea gracilis* Claus, 1879a, p. 186(40)
*Paralycaea gracilis:* Claus, 1887, p. 64, pl. 20, figs. 1–11
*Paralycaea gracilis:* Stephensen, 1925, p. 165, fig. 62
*Paralycaea gracilis:* Pirlot, 1930, p. 30, fig. 10

*Material Examined* – 8NS (0–1–0–0), 9NM (0–1–0–0).

*Distribution* – Warmer waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Dick 1970). Reported from the western North Atlantic (Harbison et al. 1977), and the north central Gulf of Mexico (present study).

#### *Sympronoe parva* (Claus)

*Parapronoe parva* Claus, 1879a, p. 177(31)
*Parapronoe parva:* Claus, 1887, p. 55, pl. 14, figs. 13–18
*Sympronoe parva:* Stebbing, 1888, p. 1533, pl. 192
*Sympronoe parva:* Shoemaker, 1945, p. 246

*Material Examined* – 9NB (0–1–0–0).

*Distribution* – Warmer waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Dick 1970). Reported from the western North Atlantic (Shoemaker 1945, Harbison et al. 1977), the Caribbean near Barbados (Lewis and Fish 1969), and the northern Gulf of Mexico (Bullis and Thompson 1965).

### Family Lycaeidae

#### *Lycaea vincentii* Stebbing

*Lycaea vincentii* Stebbing, 1888, p. 1563, pl. 199
*Lycaea vincentii:* Barnard, 1930, p. 429, fig. 57
*Lycaea vincentii:* Harbison, 1976, p. 152, figs. 12, 13

*Material Examined* – 12DS (2–0–0–0).

*Distribution* – In question. Reported from the Cape Verde Islands (Stebbing 1888), the western North Atlantic (Harbison 1976, Madin and Harbison 1977), the Caribbean Sea (Madin and Harbison 1977), and the north central Gulf of Mexico (present study).

*Remarks* – Shoemaker (1945) synonymized *L. bovallii, L. bovallioides,* and *L. vincentii* with *L. pulex.* Harbison and Madin (1976) provided a key to eight species of *Lycaea,* treating the species collected in the present study separately.

Records of *L. pulex* from Bermuda (Shoemaker 1945), Cuba (Shoemaker 1948), and the distribution records presented by Dick (1970) may, therefore, include species of *Lycaea* treated here.

#### *Lycaea bovallioides* Stephensen

*Lycaea bovallioides* Stephensen, 1925, p. 169, fig. 63
*Lycaea bovallioides:* Harbison and Madin, 1976, p. 165, fig. 5A

*Material Examined* – 1DB (0–1–0–0).
*Distribution* – Warm waters of the Atlantic Ocean and the Mediterranean Sea (Stephensen 1925). Reported from the tropical western North Atlantic (Evans 1961). The present record is the first for the Caribbean Sea-Gulf of Mexico region.
*Remarks* – See "Remarks" under *L. vincentii.*

#### *Lycaea bovallii* Chevreux

*Lycaea bovallii* Chevreux, 1900, p. 157, pl. 18, fig. 3
*Lycaea bovallii:* Stephensen, 1925, p. 168
*Lycaea bovallii:* Harbison and Madin, 1976, p. 165, fig. 3A

*Material Examined* – 7NB (0–1–0–0).
*Distribution* – Warm waters of the Atlantic Ocean and the Mediterranean Sea (Stephensen 1925). The present record is the first for the Caribbean Sea-Gulf of Mexico region.
*Remarks* – See "Remarks" under *L. vincentii.*

#### *Brachyscelus* spp.

*Remarks* – Large numbers of *Brachyscelus* spp. were found in the present study. The vast majority of specimens were females and small juveniles, making specific identification difficult. A few large male specimens agreed with the description of *Brachyscelus rapax* (syn. *Thamyris rapax* Claus, 1879). The taxonomic status of *B. rapax* is in question (Dick 1970), and a reexamination of the type specimen(s) is needed to clarify its relationship to the other species of *Brachyscelus.*

Shoemaker (1948) has reported *B. crusculum, B. globiceps,* and *B. macrocephalus* from Bahia Corrientes, Cuba.

### Family Oxycephalidae

#### *Oxycephalus clausi* Bovallius

*Oxycephalus clausi* Bovallius, 1887, p. 35
*Oxycephalus clausi:* Bovallius, 1890, p. 60, pl. 1, figs. 19–24, pl. 2, fig. 1; figs. 4, 7, 8, 22, 54, 65 (in text)
*Oxycephalus clausi:* Fage, 1960, p. 20, figs. 11–16
*Oxycephalus clausi:* Pillai, 1966a, p. 174, pl. 1–B, C; fig. 3 (in text)

*Material Examined* – 2DS (0–2–0–2), 3DS (1–1–0–0), 4DS (0–1–0–0), 10NB (0–1–0–0).
*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean and Red seas (Dick 1970). Recorded from the western North Atlantic (Fage 1960, Harbison et al. 1977, Madin and Harbison 1977), near Bermuda (Shoemaker 1945), the Caribbean waters off Puerto Rico, Cuba and Panama, the Florida Straits (Fage 1960), and the northern Gulf of Mexico (Springer and Bullis 1956).

#### *Oxycephalus piscator* Milne-Edwards

*Oxycephalus piscatoris* Milne-Edwards, 1830, p. 396
*Oxycephalus piscator:* Bovallius, 1890, p. 56, pl. 1, figs. 8–16; figs. 33, 35–37, 41, 42, 66, 68, 69, 75 (in text)
*Oxycephalus piscator:* Shoemaker, 1945, p. 246, figs. 42, 43
*Oxycephalus piscator:* Pillai, 1966a, p. 176, fig. 4

*Material Examined* – 3DS (1–0–0–0), 8DB (0–1–0–0).
*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Dick 1970). Recorded from the western North Atlantic (Fage 1960, Evans 1961), near Bermuda (Shoemaker 1945), the Caribbean waters off Cuba and Puerto Rico, the Florida Straits (Fage 1960), and the north central Gulf of Mexico (present study).

#### *Cranocephalus scleroticus* (Streets)

*Oxycephalus scleroticus* Streets, 1878, p. 281, pl. 2, fig. 3
*Cranocephalus goesi:* Bovallius, 1890, p. 95, pl. 4, figs. 7–9; figs. 5, 53, 72 (in text)
*Cranocephalus scleroticus:* Shoemaker, 1945, p. 251, fig. 44
*Cranocephalus scleroticus:* Fage, 1960, p. 72, figs. 44–55
*Cranocephalus scleroticus:* Pillai, 1966a, p. 184, pl. 1–I; fig. 9 (in text)

*Material Examined* – 3DS (0–1–0–0), 4DS (0–1–0–0), 8DB (0–1–0–0).
*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Dick 1970). Recorded from the western North Atlantic near Bermuda (Shoemaker 1945). The present records are the first for the Caribbean Sea-Gulf of Mexico region.

#### *Leptocotis tenuirostris* (Claus)

*Oxycephalus tenuirostris* Claus, 1871, p. 155
*Dorycephalus lindstroemi:* Bovallius, 1890, p. 76, pl. 2, figs. 16–18, pl. 3, fig. 1; figs. 31, 39, 44, 56, 73, 77 (in text)
*Leptocotis tenuirostris:* Fage, 1960, p. 37, figs. 21–24
*Leptocotis tenuirostris:* Pillai, 1966a, p. 181, pl. 1–F, G; fig. 7 (in text)

*Material Examined* – 7NM (1–0–0–0).
*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans (Dick 1970). Recorded from the western North Atlantic (Fage 1960), near Bermuda (Shoemaker 1945), the Caribbean Sea off Cuba, Puerto Rico and Panama, the Florida Straits (Fage 1960), and the north central Gulf of Mexico (present study).

### *Simorhynchotus antennarius* Claus

*Simorhynchotus antennarius* Claus, 1871, p. 156
*Simorhynchotus antennarius:* Fage, 1960, p. 11, figs. 1–3
*Simorhynchotus antennarius:* Pillai, 1966a, p. 171, pl. 1–A; figs. 1, 2 (in text)

*Material Examined* – 1DS (1–2–0–1), 3DS (312–130–22–10), 4DB (16–8–0–5), 5DS (162–80–21–15), 7NS (2–1–0–2), 8NS (0–2–0–1), 10NB (2–1–0–1).

*Distribution* – Widely distributed in warmer waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Dick 1970). Recorded from the Caribbean Sea near Barbados (Lewis and Fish 1969), Panama (Fage 1960), and the northern Gulf of Mexico (Hopkins 1966).

*Remarks* – *Simorhynchotus antennarius* was very common in coastal waters, ranking second in abundance to *Lestrigonus bengalensis.*

### *Streetsia challengeri* Stebbing

*Streetsia challengeri* Stebbing, 1888, p. 1603, pl. 207
*Streetsia challengeri:* Fage, 1960, p. 51, figs. 36–43
*Streetsia challengeri:* Pillai, 1966a, p. 189, pl. 1–L; fig. 12 (in text)

*Material Examined* – 3DS (1–0–0–0).

*Distribution* – Widely distributed in warmer waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Dick 1970). Recorded from the western North Atlantic (Fage 1960), near Bermuda (Shoemaker 1945), the Caribbean waters off Puerto Rico and Panama, the Florida Straits (Fage 1960), the central and eastern Caribbean Sea (Moryakova 1968), and the north central Gulf of Mexico (present study).

### *Streetsia mindanaonis* (Stebbing)

*Leptocotis mindanaonis* Stebbing, 1888, p. 1598, pl. 204C
*Streetsia mindanaonis:* Fage, 1960, p. 45, figs. 28–35
*Streetsia mindanaonis:* Pillai, 1966a, p. 192, pl. 1–N; fig. 14 (in text)

*Material Examined* – 10DM (0–1–0–0).

*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans (Dick 1970). Reported from waters off northeast Cuba, the Caribbean Sea near St. Croix, Puerto Rico and Panama (Fage 1960), and the north central Gulf of Mexico (present study).

### *Rhabdosoma whitei* Bate

*Rhabdosoma whitei* Bate, 1862, p. 345, pl. 54, fig. 7
*Xiphocephalus whitei:* Bovallius, 1890, p. 125, pl. 7, figs. 1–20; figs. 13–17, 24, 32, 45–49, 63, 64, 78, 79, 81–83, 85–87
*Rhabdosoma whitei:* Fage, 1960, p. 97, figs. 71–76
*Rhabdosoma whitei:* Pillai, 1966a, p. 194, fig. 15

*Material Examined* – 2DS (0–9–0–0).

*Distribution* – Widely distributed in warmer waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Dick 1970). Recorded from the western North Atlantic (Fage 1960), near Bermuda (Shoemaker 1945), the Caribbean Sea near St. Croix, Puerto Rico, Dominica and Panama, the Florida Straits (Fage 1960), and the north central Gulf of Mexico (present study).

## Family Platyscelidae

### *Platyscelus ovoides* (Claus)

*Eutyphis ovoides* Claus, 1879a, p. 155(9)
*Eutyphis globosus:* Claus, 1879a, p. 159(12)
*Platyscelus ovoides:* Shoemaker, 1945, p. 256, figs. 47, 48

*Material Examined* – 10DB (0–1–0–0).

*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Dick 1970). Reported from the western North Atlantic near Bermuda (Shoemaker 1945), and the northern Gulf of Mexico (Springer and Bullis 1956, Bullis and Thompson 1965).

### *Hemityphis rapax* (Milne-Edwards)

*Typhis rapax* Milne-Edwards, 1830, p. 395
*Hemityphis tenuimanus:* Claus, 1887, p. 38, pl. 4, figs. 1–13
*Hemityphis crustulatus:* Claus, 1887, p. 39, pl. 4, figs. 14–22
*Hemityphis rapax:* Shoemaker, 1945, p. 259

*Material Examined* – 10NM (0–1–0–0).

*Distribution* – Widely distributed in warmer waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Dick 1970). Reported from the western North Atlantic (Shoemaker 1945, Harbison et al. 1977), the Caribbean Sea off Barbados (Lewis and Fish 1969), and the northern Gulf of Mexico (Bullis and Thompson 1965).

### *Paratyphis maculatus* Claus

*Paratyphis maculatus* Claus, 1879a, p. 160(14)
*Paratyphis maculatus:* Claus, 1887, p. 39, pl. 5, figs. 1–9
*Paratyphis maculatus:* Shoemaker, 1948, p. 15

*Material Examined* – 3DS (0–1–0–0), 9DM (0–1–0–0).

*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans (Dick 1970). Reported from the western North Atlantic near Bermuda (Shoemaker 1945), Bahia Corrientes on the southwest coast of Cuba (Shoemaker 1948), and the north central Gulf of Mexico (present study).

### *Tetrathyrus forcipatus* Claus

*Tetrathyrus forcipatus* Claus, 1879a, p. 160(14)
*Tetrathyrus forcipatus:* Claus, 1887, p. 40, pl. 5, figs. 10–18, pl. 6, figs. 1–3
*Tetrathyrus forcipatus:* Chevreux and Fage, 1925, p. 422, fig. 415
*Tetrathyrus forcipatus:* Pillai, 1966b, p. 230, fig. 19

*Material Examined* – 1DS (2–0–0–0), 2DS (0–1–0–0), 3DB (9–14–0–0), 3DS (4–0–0–0), 4DB (1–2–0–1), 5DS (1–1–0–0), 7NS (1–2–0–2), 8DB (1–1–0–2), 9DM (3–7–0–3), 12DS (0–1–0–2).

*Distribution* – Widely distributed in warmer waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean and Red seas (Dick 1970). Reported from the tropical western North Atlantic (Evans 1961, Harbison et al. 1977), near Bermuda (Shoemaker 1945), Bahia Corrientes on the southwestern coast of Cuba (Shoemaker 1948), and the north central Gulf of Mexico (present study).

*Remarks* – *Tetrathyrus forcipatus* was commonly found in coastal and offshore samples, ranking third in total abundance.

#### *Amphithyrus bispinosus* Claus

*Amphithyrus bispinosus* Claus, 1879a, p. 161(15)
*Amphithyrus bispinosus:* Claus, 1887, p. 41, pl. 6, figs. 4–16
*Amphithyrus bispinosus:* Shoemaker, 1945, p. 259

*Material Examined* – 10DB (0–1–0–0).

*Distribution* – Widely distributed in warmer waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Dick 1970). Reported from the western North Atlantic near Bermuda (Shoemaker 1945), the Caribbean Sea off Barbados (Lewis and Fish 1969), and the north central Gulf of Mexico (present study).

#### *Amphithyrus sculpturatus* Claus

*Amphithyrus sculpturatus* Claus, 1879a, p. 162(16)
*Amphithyrus sculpturatus:* Claus, 1887, p. 41, pl. 7, figs. 1–9
*Amphithyrus orientalis:* Shoemaker, 1925, p. 58, figs. 25, 26
*Amphithyrus sculpturatus:* Shoemaker, 1948, p. 14

*Material Examined* – 10DB (0–1–0–0).

*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Dick 1970). Reported from the western North Atlantic (Harbison et al. 1977), Bahía Corrientes, Cuba (Shoemaker 1948), and the north central Gulf of Mexico (present study).

### Family Parascelidae

#### *Thyropus edwardsii* (Claus)

*Parascelus edwardsii* Claus, 1879a, p. 164(18)
*Parascelus edwardsii:* Claus, 1887, p. 46, pl. 10, figs. 1–11
*Parascelus zebu:* Stebbing, 1888, p. 1496, pl. 185
*Parascelus edwardsii:* Shoemaker, 1945, p. 260

*Material Examined* – 8DB (0–1–0–0).

*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean and Red seas (Dick 1970). Reported from the tropical western North Atlantic (Evans 1961, Harbison et al. 1977), near Bermuda (Shoemaker 1945), the Caribbean Sea off Barbados (Lewis and Fish 1969, Moore and Sander 1977, Harbison et al. 1977), and the north central Gulf of Mexico (present study).

*Remarks* – Bowman and Gruner (1973) placed the genus *Parascelus* Claus, 1879 in synonomy with *Thyropus* Dana, 1852.

#### *Thyropus typhoides* (Claus)

*Parascelus typhoides* Claus, 1879a, p. 165(19)
*Parascelus typhoides:* Claus, 1887, p. 46, pl. 9, figs. 12–16, pl. 10, figs. 12, 13
*Parascelus typhoides:* Chevreux and Fage, 1925, p. 424, fig. 416
*Parascelus typhoides:* Pillai, 1966b, p. 227, fig. 17

*Material Examined* – 7NM (0–1–0–0).

*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean and Red seas (Dick 1970). Reported from the western North Atlantic near Bermuda (Shoemaker 1945). This is the first record of this species from the Caribbean Sea-Gulf of Mexico region.

#### *Thyropus sphaeroma* (Claus)

*Tanyscelus sphaeroma* Claus, 1879a, p. 163(17)
*Tanyscelus sphaeroma:* Claus, 1887, p. 45, pl. 8, figs. 1–11
*Thyropus danae:* Stebbing, 1888, p. 1492, pl. 210C
*Thyropus sphaeroma:* Spandl, 1927, p. 259, figs. 53, 54, p. 284, fig. 63
*Thyropus sphaeroma:* Shoemaker, 1945, p. 260

*Material Examined* – 6NM (0–1–0–0).

*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans (Dick 1970). Reported from the western North Atlantic (Shoemaker 1945, Harbison et al. 1977). This is the first record of this species from the Caribbean Sea-Gulf of Mexico region.

#### *Schizoscelus ornatus* Claus

*Schizoscelus ornatus* Claus, 1879a, p. 167(21)
*Schizoscelus ornatus:* Claus, 1887, p. 44, pl. 10, figs. 1–11
*Schizoscelus ornatus:* Stebbing, 1888, p. 1504, pl. 210D
*Schizoscelus ornatus:* Spandl, 1927, p. 255, fig. 52

*Material Examined* – 3DS (2–0–0–0), 4DB (0–1–0–0), 11DS (0–0–1–0).

*Distribution* – Warm waters of the Atlantic, Pacific, and Indian oceans, and the Mediterranean Sea (Dick 1970). Reported from the western North Atlantic (Harbison et al. 1977), and the north central Gulf of Mexico (present study).

ACKNOWLEDGMENTS

The authors express their appreciation to Thomas E. Bowman of the National Museum of Natural History for his critical review of the manuscript and confirmation of identifications of selected species. Also, thanks to Malcolm Ware and Hannah Cake of the Gunter Library, Gulf Coast Research Laboratory, for their invaluable assistance in obtaining literature essential to the preparation of this report, and to Sharon Wilson for typing the manuscript.

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## NOTE ADDED IN PROOF:

The authors thank Mr. Kenneth A. Kimball for supplying several obscure references concerning hyperiid records in the Caribbean Sea-Gulf of Mexico region. These additional references were not received in time to be incorporated within the original text of this report. Included are Senna (1906) who reported a number of hyperiid genera from the Caribbean Sea-Gulf of Mexico waters; Colosi (1918), who reported *Dorycephalus lindstroemi* from the Caribbean Sea; and Suarez-Caabro and Duarte-Bello (1961) who included *Eupronoe armata, Platyscelus ovoides,* and *Parascelus typhoides* among a list of hyperiids from Caribbean waters off Cuba.

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# Gulf Research Reports

Volume 6 | Issue 4

January 1980

Enterovirus and Bacterial Evaluation of Mississippi Oysters

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DOI: 10.18785/grr.0604.04


Recommended Citation

Ellender, R., D. Cook, V. Sheladia and R. Johnson. 1980. Enterovirus and Bacterial Evaluation of Mississippi Oysters. Gulf Research Reports 6 (4): 371-376.
Retrieved from http://aquila.usm.edu/gcr/vol6/iss4/4

*Gulf Research Reports*, Vol. 6, No. 4, 371–376, 1980.

# ENTEROVIRUS AND BACTERIAL EVALUATION OF MISSISSIPPI OYSTERS

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*ABSTRACT* The numbers of enteric viruses and fecal coliform bacteria in oysters and water samples collected along the Mississippi Gulf coast during 1979 were determined. Ten viral isolates, representing members of the poliovirus group, were identified from an approved oyster harvesting site. The number of virus isolations increased to 51 when oysters were collected from a prohibited harvesting location. The majority of isolates were identified as poliovirus type 1 or 2, coxsackievirus B3 and B4, and echovirus type 24. Fecal coliforms in water samples collected at approved and prohibited locations confirmed the classification assigned to each area by the Mississippi State Board of Health. The numbers of fecal coliforms in oyster samples collected at the identical sites did not reflect the levels observed in water samples. There was no positive correlation between indicator bacteria in the water column and the number of viruses in the shellfish examined. These results imply that viral analyses of shellfish may be needed as an adjunct to bacteriological analyses so that shellfish safety is verified.

## INTRODUCTION

Since the early 1900s, bacterial indices (as exemplified by the coliform count) have been used to demonstrate the degree of fecal pollution of water, including marine waters (Hunt 1977). As pollution levels have increased, the number of approved shellfish reefs has declined. The shellfish industry has lost ground steadily and today is becoming more dependent on relaying and depuration practices for survival.

Viral contamination of polluted shellfish does occur (Bendenelli and Rucchi 1969, Metcalf and Stiles 1968, Fugate et al. 1975, Denis 1973, Goyal et al. 1979, Gerba and Goyal 1978, Gerba et al. 1979, Portnoy et al. 1975), and usually includes those groups with direct or indirect association with the alimentary tract of man or animals. The characteristics of particular viral groups also allow for survival and transmission via feces. The entero-, reo-, rota- and adenoviruses, and hepatitis A virus all are transmitted through sewage and have the potential to contaminate shellfish growing waters.

Enteric viruses do not reproduce in oysters but are concentrated from the surrounding water when the animal feeds (Chang et al. 1971). The digestive gland of the oyster harbors the greatest viral concentration (Liu et al. 1966) but other tissues will adsorb virus particles. Since polluted oysters usually contain low-level viral contamination, sample extraction and concentration are necessary. Recent investigations (Fugate et al. 1975; Sobsey et al. 1975, 1978; Tierney et al. 1980; Metcalf et al. 1980; Landry et al. 1980; Goyal et al. 1979; Herrman and Cliver 1968a, 1968b; Kostenbader and Cliver 1972; Vaughn et al. 1980; Ellender et al. 1980) have evaluated the extent of viral contamination of shellfish by various methods of extraction.

Many researchers now recognize that fecal coliform counts in surface waters do not reflect the level of viral contamination of shellfish. Recent investigations (Gerba et al. 1979, Portnoy et al. 1975, Mackowiak et al. 1976) have shown that (1) enteric viruses can be present in acceptable levels, (2) viruses remain viable in the estuarine environment, (3) shellfish concentrate viruses from the surrounding water and prolong virus survival, (4) particulate matter in estuaries decreases virus inactivation, and (5) viruses adsorbed to particulates can be introduced into the water column by changes in the chemical and physical environment.

The purpose of this study was to evaluate fecal coliform and enterovirus levels in oysters taken from both approved and prohibited growing waters along the Mississippi Gulf coast. Data also were collected on the levels of fecal coliforms in surface and bottom water samples. A summary of results of the first year (1978) has been published (Ellender et al. 1980). This report presents the results of the 1979 collections and discusses the fluctuations of fecal coliform and enterovirus levels observed during the 2-year period, 1978–1979.

## MATERIAL AND METHODS

### *Collection of Samples*

Composite oyster samples (five 150-gram [gr] lots) (*Crassostrea virginica*) were collected from Pass Christian Reef (approved area) and from Graveline Bayou (prohibited area), and assayed for bacterial and viral levels. Pass Christian Reef was sampled monthly; Graveline Bayou was sampled biweekly. This sampling schedule was based on the premise that the majority of virus isolations would occur in samples of prohibited oysters. These samples were kept cool in an ice chest during transit and shucked upon arrival at the laboratory. Samples were either processed immediately or stored in sterile plastic bags at -75°C. Water samples (surface and bottom) at each location were collected using a J–Z sampler. At the Graveline Bayou location, water samples

Manuscript received September 26, 1980; accepted October 7, 1980.

were collected at three stations for three days prior to oyster sampling and on the days of oyster sampling. Three stations at the Pass Christian location were sampled on the day of oyster collection.

Temperature and salinity records were collected as described by Ellender et al. (1980).

*Analysis of Fecal Coliforms and Viruses*

Fecal coliform bacteria were determined in oyster and water samples according to standard methods (American Public Health Association 1970). Virus contamination of oyster samples was determined according to procedures described by Ellender et al. (1980). Briefly, samples were extracted by a modification of the adsorption-elution procedure of Sobsey et al. (1975). Sample concentrates were assayed according to the plaque method in the Buffalo green monkey (BGM) kidney cell line. Plaques were confirmed as viruses by three passages in BGM cells and were identified serologically.

## RESULTS

Fecal coliform counts in oyster and water samples taken from Pass Christian and Graveline Bayou stations are summarized in Table 1. The three sampling stations at Pass Christian were located in the same general area and usually contained similar numbers of fecal coliform bacteria in surface and bottom water samples. On occasion, however, differences did exist between samples collected at the two levels, surface and bottom. Fecal coliform counts in the water generally were lower during the summer and fall, but increased during the winter and spring months. The most probable number (MPN) median fecal coliform for all surface and bottom water samples during 1979 was $< 2$ per 100 ml. Only those samples collected in February and December 1979, contained counts greater than 43 per 100 ml. Fecal coliforms in oysters sampled at Pass Christian ranged from $< 20$ to 11,000 per 100 gr. The median fecal coliform count of all samples collected during the 12-month period (January through December 1979) was 88 per 100 gr. Except for samples taken in December, there appeared to be no correlation between fecal coliform counts in water and oyster samples collected at the same time in that area.

As with the Pass Christian samples, data collected at all three Graveline Bayou stations on the same day were similar. However, data collected on each of the four consecutive sampling days could vary significantly depending on local meteorological and hydrographical conditions. Of the 24 surface and bottom water median values recorded (Table 1), only one did not exceed a value of 14 per 100 ml. In addition, 66% of the MPN values exceeded 43 per 100 ml, indicating that the "prohibited" classification of Graveline Bayou is warranted. Fecal coliform levels in oysters collected at Graveline ranged from $< 20$ to 1,700 per 100 gr. The median MPN value for all samples was 140 per 100 gr. This figure was higher than the median value recorded for all oyster samples examined from Pass Christian.

Virus isolations from oysters collected at the approved site are presented in Table 2. From 32 samples representing 343 oysters, 53 plaque-like isolates (PLI) were examined. Of these, ten (19%) were confirmed as viruses; all were classified as poliovirus type 1 or type 2. The largest number of viruses isolated in a single month was eight. These were found in February samples, but this finding was not consistent with virus isolations during other winter months. Two virus isolations were made during June and July. Overall, the low frequency of virus isolation at Pass Christian sampling sites was consistent with the general trend observed in the number of indicator bacteria collected at the same location. This finding is supported by the fact that only 4 of the 32 samples analyzed (13%) contained confirmed virus isolates.

**TABLE 1.**

**Fecal coliform levels in water and oyster samples taken during 1979.**

| | Pass Christian Reef | | | Graveline Bayou | | |
|---|---|---|---|---|---|---|
| | Water | | | Water | | |
| | Median MPN/100 ml | | Oyster | Median MPN/100 ml | | Oyster |
| Month | Surface | Bottom | Mean MPN/100 gr | Surface | Bottom | Mean MPN/100 gr |
| January | 23 | 20 | 90 | 38 | 25 | 70 |
| February | 47 | 70 | 50 | 650 | 730 | 120 |
| March | $< 2$ | 3 | 130 | 68 | 75 | 30 |
| April | 27 | 26 | 130 | 420 | 340 | 49 |
| May | 8 | $< 2$ | 7,800 | 48 | 56 | 750 |
| June | 3 | $< 2$ | 250 | 87 | 60 | 320 |
| July | $< 2$ | $< 2$ | 400 | 18 | 13 | 120 |
| August | $< 2$ | $< 2$ | 20 | 33 | 34 | 94 |
| September | $< 2$ | $< 2$ | 80 | 37 | 36 | 190 |
| October | $< 2$ | 3 | 40 | 97 | 83 | 140 |
| November | 10 | 3 | 360 | 880 | 700 | 1,200 |
| December | 60 | 120 | 3,300 | 230 | 260 | 1,100 |

TABLE 2.

Natural viral analysis of approved oysters, Pass Christian Reef, 1979.

| Month | Number of Oysters/ Number of Samples | Number of Samples Containing Confirmed Virus Isolates | Number of Plaque-like Isolates Total: per 100 gr | Number of Plaques Identified as Viruses Total: per 100 gr |
|---|---|---|---|---|
| January | 30/ 3 | 0 | 20.0: 4.4 | 0.0:0.0 |
| February | 31/ 4 | 2 | 17.0: 2.8 | 8.0:1.3 |
| March | 29/ 3 | 0 | 1.0: 0.2 | 0.0:0.0 |
| April | 23/ 3 | 0 | 3.0: 0.7 | 0.0:0.0 |
| May | 31/ 3 | 0 | 0.0: 0.0 | 0.0:0.0 |
| June | 28/ 3 | 1 | 3.0: 0.7 | 1.0:0.2 |
| July | 36/ 3 | 1 | 1.0: 0.2 | 1.0:0.2 |
| August | 29/ 2 | 0 | 6.0: 2.0 | 0.0:0.0 |
| September | 36/ 2 | 0 | 0.0: 0.0 | 0.0:0.0 |
| October | 23/ 2 | 0 | 0.0: 0.0 | 0.0:0.0 |
| November | 28/ 2 | 0 | 1.0: 0.3 | 0.0:0.0 |
| December | 18/ 2 | 0 | 1.0: 0.3 | 0.0:0.0 |
| Total | 343/32 | 4 | 53 | 10 |

Of 94 oyster samples (representing 1,043 oysters) collected at Graveline Bayou during 1979, 18 (19%) contained virus particles (Table 3). In prohibited oysters, 673 plaque-like isolates were found; 51 viruses were confirmed. The March samples accounted for 74% of the PLI, and 71% of the confirmed viruses. Viruses also were isolated during the months of April (3), June (1), July (2), August (3), September (5), and December (1). Of all virus isolations at the Graveline Bayou location, 83% were poliovirus types 1 and 2; 7% were represented by coxsackievirus types B3 and B4; 1% by echovirus type 24, and the remaining 9% could not be identified by the serological methods employed.

Table 4 summarizes the physical data collected during 1979. Surface- and bottom-water salinities did not vary significantly on a month-to-month basis at the Pass Christian site. The averages of the salinities recorded during 1979 were 11.5 and 14.7 parts per thousand (ppt) for surface and bottom waters, respectively. In general, the higher values were recorded during the winter and fall months. Salinity extremes were greater in Graveline Bayou than on Pass Christian Reef. Average surface and bottom salinities in Graveline Bayou were 7.8 and 9.2 ppt, respectively. As expected, temperatures were highest from May to September at both sampling locations.

It is clear from a summary of project data (Table 5) that the percentage of samples containing virus is not consistent

TABLE 3.

Natural viral analysis of prohibited oysters, Graveline Bayou, 1979.

| Month | Number of Oysters/ Number of Samples | Number of Samples Containing Confirmed Virus Isolates | Number of Plaque-like Isolates Total: per 100 gr | Number of Plaques Identified as Viruses Total: per 100 gr |
|---|---|---|---|---|
| January | 39/ 3 | 0 | 17.0: 3.8 | 0.0:0.0 |
| February | 91/ 9 | 0 | 42.0: 3.1 | 0.0:0.0 |
| March | 75/10 | 3 | 503.0:33.5 | *36.0:2.4 |
| April | 89/10 | 2 | 70.0: 4.7 | 3.0:0.2 |
| May | 88/10 | 0 | 0.0: 0.0 | 0.0:0.0 |
| June | 104/10 | 1 | 2.0: 0.1 | 1.0:0.1 |
| July | 125/10 | 2 | 19.0: 1.3 | 2.0:0.1 |
| August | 117/ 9 | 3 | 5.0: 0.4 | 3.0:0.2 |
| September | 114/ 8 | 3 | 6.0: 0.5 | 5.0:0.4 |
| October | 88/ 7 | 0 | 0.0: 0.0 | 0.0:0.0 |
| November | 74/ 6 | 0 | 1.0: 0.1 | 0.0:0.0 |
| December | 21/ 2 | 1 | 4.0: 1.3 | 1.0:0.3 |
| Total | 1043/94 | 18 | 673 | 51 |

*Forty plaques purified and typed.

TABLE 4.

Salinity (ppt) and temperature (°C) measurements, 1979

| | Pass Christian | | | Graveline Bayou | | |
|---|---|---|---|---|---|---|
| | Salinity | | | Salinity | | |
| Month | Surface | Bottom | Temp. | Surface | Bottom | Temp. |
| Jan | 13 | 14 | 6 | 16 | 19 | 7 |
| Feb | 7 | 10 | 15 | 2 | 3 | 11 |
| Mar | 5 | 5 | 19 | 3 | 3 | 15 |
| Apr | 2 | 2 | 20 | 1 | 1 | 19 |
| May | 4 | 8 | 22 | 4 | 3 | 21 |
| Jun | 14 | 14 | 29 | 12 | 12 | 26 |
| Jul | 8 | 19 | 32 | 4 | 7 | 32 |
| Aug | 19 | 19 | 31 | 10 | 11 | 30 |
| Sep | 17 | 18 | 29 | 9 | 10 | 30 |
| Oct | 19 | 19 | 17 | 15 | 16 | 21 |
| Nov | 18 | 18 | 11 | 10 | 13 | 15 |
| Dec | 12 | 12 | 9 | 8 | 12 | 7 |

TABLE 5.

Project summary: 1978–1979.

| | 1978 | | 1979 | | Total | |
|---|---|---|---|---|---|---|
| | PC[1] | GB[2] | PC | GB | PC | GB |
| Number of samples examined: | 22 | 87 | 32 | 94 | 54 | 181 |
| Number of samples containing virus: | 2 | 30 | 4 | 18 | 6 | 48 |
| Percent of samples containing virus: | 9 | 35 | 13 | 19 | 11 | 27 |
| Number of months in which viruses were isolated: | 2 | 12 | 3 | 7 | 5 | 19 |
| Percent of months virus isolated: | 17 | 100 | 25 | 58 | 21 | 79 |

[1] Pass Christian (approved) Reef
[2] Graveline Bayou (prohibited)Reef

on a year-to-year basis. Only 9% of 1978 Pass Christian Reef samples contained virus as compared to 13% in the following year. The reverse occurred at the prohibited sampling location (1978, 35%; 1979, 19%). These trends again are observed in the data of the number of months in which viruses were isolated. During the 12 months of 1978, only 2 months (17%) yielded samples containing viruses. This percentage increased to 25% during 1979. All 12 months of 1978, Graveline Bayou samples were positive for virus. This figure, however, dropped to 7 months (58%) during the subsequent 12-month period. Although the number of samples collected at the Graveline Bayou site during the 2-year period was higher than the number of approved-site samples collected, statistical testing did demonstrate that the two locations were significantly different in relation to the number of virus-containing samples that were examined (probability [P] $\leq 0.01$).

Tables 6 and 7 indicate the degree of correlation for all measured parameters during the 24 months of sampling. They indicate the inability of fecal coliform water analyses to predict the contamination of shellfish meats by virus particles. At the approved collection site, strong correlations were observed between surface- and bottom-water salinities, temperatures and salinities in the water column, and fecal coliform counts in surface and bottom waters. Plaque-like isolates did correlate with confirmed virus levels. Certain moderate relationships between different parameters also were present in Graveline Bayou samples. Moderate correlations did exist between (1) fecal coliforms in oyster tissue and the number of PLI observed, and (2) confirmed virus isolations and the month of the year. A weak positive correlation was observed between the numbers of plaque-like isolates and the numbers of confirmed viruses.

## DISCUSSION

The results of this study stress the need to better understand the complex relationships of shellfish virology. Virus isolations during the 2-year period were variable and often clustered in small groups of samples. This suggests that intermittent contamination, rather than chronic contamination, of shellfish-growing waters plays a significant role in the level of contamination observed and may require frequent sampling by health agencies responsible for classification of shellfish-growing waters. Graphic representations of fecal coliform analysis of water and oyster samples followed cyclic patterns which generally were higher during the winter and summer months at each of the locations tested. However, such patterns were not related to the individual month of sampling and they underscore the need to analyze samples frequently from a shellfish-harvesting area for reef classification.

Those data suggest that virus levels in shellfish are not always consistent with the levels of indicator bacteria used to classify estuarine growing areas. This failure of the bacterial-indicator concept lends credence to the search for a virus which could signify a potentially dangerous situation. Often polioviruses are suggested as a representative group since they are commonly found in human feces as a result of widespread vaccination. In this study, the majority of oyster-associated viruses were poliovirus type 1. Type 2 was isolated infrequently. Since there are three serotypes in the vaccine in approximately equal proportions, the frequent isolation of a single type from oyster samples could mean that the extraction method is more selective for that serotype, that the viruses are not shed in equal numbers, or that the estuarine environment or the shellfish population favors the viability on only certain strains. Laboratory experiments do not suggest that extraction procedures are selective, but other work (R. D. Ellender and D. W. Cook, unpublished) has implied that oysters do not take

TABLE 6.

Correlation Coefficients: Pass Christian Reef
January 1978 to December 1979

| | Month | Water Salinity Surface | Water Salinity Bottom | Temperature °C | Fecal Coliforms Surface Water 100 ml | Fecal Coliforms Bottom Water 100 ml | Fecal Coliforms Oyster Tissue 100 gr | Plaque-like Isolates: 100 gr | Confirmed Virus Isolates: 100 gr |
|---|---|---|---|---|---|---|---|---|---|
| Month | 1.00000 | | | | | | | | |
| Water salinity | | | | | | | | | |
| Surface | *0.41101 | 1.00000 | | | | | | | |
| Bottom | 0.32886 | *0.92442 | 1.00000 | | | | | | |
| Temperature °C | 0.36257 | *0.67603 | *0.88680 | 1.00000 | | | | | |
| Fecal coliforms: | | | | | | | | | |
| Surface water: 100 ml | 0.28354 | 0.13814 | 0.15305 | 0.13364 | 1.00000 | | | | |
| Bottom water: 100 ml | 0.11745 | 0.15036 | 0.16546 | 0.15509 | *0.75231 | 1.00000 | | | |
| Oyster tissue: 100 g | 0.01410 | 0.03685 | 0.07147 | 0.08420 | 0.10549 | 0.00211 | 1.00000 | | |
| Plaque-like isolates: 100 gr | 0.22307 | 0.15595 | 0.20168 | 0.23140 | 0.08989 | 0.07562 | 0.24259 | 1.00000 | |
| Confirmed virus isolates: 100 gr | 0.18918 | 0.09406 | 0.11528 | 0.11215 | 0.08654 | 0.08488 | 0.13768 | *0.78575 | 1.00000 |

*Numbers significant at $P \leqslant 0.05$ level of significance.

TABLE 7.

Correlation Coefficients: Graveline Bayou
January 1978 to December 1979

| | Month | Water Salinity Surface | Water Salinity Bottom | Temperature °C | Fecal Coliforms Surface Water 100 ml | Fecal Coliforms Bottom Water 100 ml | Fecal Coliforms Oyster Tissue 100 gr | Plaque-like Isolates: 100 gr | Confirmed Virus Isolates: 100 gr |
|---|---|---|---|---|---|---|---|---|---|
| Month | 1.00000 | | | | | | | | |
| Water salinity | | | | | | | | | |
| Surface | 0.18698 | 1.00000 | | | | | | | |
| Bottom | 0.21181 | *0.96757 | 1.00000 | | | | | | |
| Temperature °C | 0.02834 | 0.00204 | 0.07350 | 1.00000 | | | | | |
| Fecal coliforms: | | | | | | | | | |
| Surface water: 100 ml | 0.14853 | 0.02910 | 0.08070 | 0.07254 | 1.00000 | | | | |
| Bottom water: 100 ml | 0.03053 | 0.21243 | 0.18425 | 0.40043 | *0.48042 | 1.00000 | | | |
| Oyster tissue: 100 g | 0.31583 | 0.22894 | 0.21780 | 0.03852 | 0.10075 | 0.15296 | 1.00000 | | |
| Plaque-like isolates: 100 gr | 0.27614 | 0.10952 | 0.11902 | 0.21291 | 0.09917 | 0.12708 | *0.55320 | 1.00000 | |
| Confirmed virus isolates: 100 gr | *0.55797 | 0.19078 | 0.19876 | 0.10390 | 0.22032 | 0.07284 | 0.05285 | *0.45160 | 1.00000 |

*Numbers significant at $P \leqslant 0.05$ level of significance.

up coxsackievirus A-9 or echovirus type 3 as efficiently as poliovirus type 1.

These studies also demonstrate that classification of oyster-growing waters eventually may require additional changes which relate to virus contamination. The approved location examined in this study did contain low-level virus concentrations. If this observation is true for other "approved" oyster beds, the use of the fecal coliform

indicator concept will lose credibility.

Recent studies (R. D. Ellender, unpublished) suggest that viruses which enter the marine ecosystem adsorb to estuarine sediments which preserve their infectivity. Sediment may act as virus reservoirs which, when influenced by chemical or physical action, release virus back into the water column. Shellfish contamination may thus occur by a mechanism which is independent of the numbers of indicator bacteria in the growing waters. If it can be shown that viruses or fecal coliforms in sediments do correlate with virus numbers in shellfish, an additional mechanism will be available to predict potential disease outbreaks from the consumption of shellfish products.

## ACKNOWLEDGMENTS

This study was supported by funds from the Mississippi-Alabama Sea Grant Program of the National Oceanic and Atmospheric Administration, Office of Sea Grant, Department of Commerce, grant number 04–8–M01–92. The U.S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright notation that may appear hereon.

The authors thank John Supan, of the Gulf Coast Research Laboratory (GCRL), for sample collection, Sandra Lofton and Alan Criss, of the GCRL, for bacteriological analysis, and Jerry Tsao, of the University of Southern Mississippi, for assistance in virological identification.

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# Gulf Research Reports

Volume 6 | Issue 4

January 1980


## Growth and Residency of Juvenile Fishes Within a Surf Zone Habitat in the Gulf of Mexico


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DOI: 10.18785/grr.0604.05





### Recommended Citation

Modde, T. 1980. Growth and Residency of Juvenile Fishes Within a Surf Zone Habitat in the Gulf of Mexico. Gulf Research Reports 6 (4): 377-385.
Retrieved from http://aquila.usm.edu/gcr/vol6/iss4/5

*Gulf Research Reports*, Vol. 6, No. 4, 377–385, 1980.

# GROWTH AND RESIDENCY OF JUVENILE FISHES WITHIN A SURF ZONE HABITAT IN THE GULF OF MEXICO

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*ABSTRACT* Over a 32-month study period, 154,469 fish representing 76 species were collected from the Gulf shore of Horn Island, Mississippi. Fishes collected were identified as either resident or migrant species according to length frequency data. The migrant component, dominated numerically by *Anchoa lyolepis*, represented the greatest number of species and individuals collected. Resident fishes constituted only six species but comprised 42.0% of all fish captured. The more abundant species residing within the Horn Island surf zone, *Trachinotus carolinus*, *Menticirrhus littoralis*, and *Harengula jaguana*, appeared to utilize this habitat as a nursery for approximately 3 months throughout the spring and summer period. Of these three residents, the two former species exhibited intermittent recruitment into the exposed beach habitat during the spring and early summer, whereas larval *H. jaguana* exhibited two distinct periods of immigration, occurring first in the late spring and again in midsummer.

## INTRODUCTION

The importance of estuaries as nursery and feeding areas for fishes is well documented in the literature (e.g., Gunter 1938, 1945; Joseph and Yerger 1956). In contrast, relatively few studies have investigated the role of high-energy beaches in the early life history of fishes. Greeley (1939), investigating an exposed beach habitat in New York, recognized three groups of fishes occupying the surf zone: permanent residents, immature summer residents, and migrants. Warfel and Merriman (1944), examining the ichthyofauna of a protected Connecticut beach, further divided the migrant category into immature offspring of breeding migrants and immature migrants produced elsewhere that moved into the shallow inshore habitat. Both beach studies observed that the greatest numerical component of fishes collected were immature individuals.

Although the surf zone of an exposed beach was characterized by Springer and Woodburn (1960) as an extreme habitat offering little environmental diversity, this habitat may provide several benefits to immature fishes. Suggested advantages of the surf zone include the abundance of food (McFarland 1963a), increased metabolic efficiency via heat acquisition (Reynolds and Thomson 1974), and protection from predators (Daly 1970). The present study was designed to evaluate the temporal association of juvenile fishes to a barrier island surf zone habitat within the northern Gulf of Mexico.

## METHODS AND MATERIALS

The study area is located along the windward shore of Horn Island, Jackson County, Mississippi. Horn Island is one of a chain of barrier islands lying parallel to the Mississippi-Alabama Gulf coast (Figure 1). The island, approximately 14 km offshore, has a length of 19 km and never exceeds 1.2 km in width. The center of the island lies at latitude 30°14′ and longitude 88°40′ (Franks 1970). The windward beach is partially protected from oceanic wind-driven waves by a series of sand bars which extend the length of the island. The exposed beach is characterized by a sand substrate, moderate wave activity, and the absence of any rooted vegetation. The study area has a diurnal tidal pattern with maximum spring amplitude of approximately 1 m. The windward shore of the northern Gulf coast barrier island system has been categorized by Odum and Copeland (1969) as a high-energy beach system.

The barrier island system functions as an effective barrier to the mixing of brackish water from Mississippi Sound and the higher salinity Gulf waters, although water is

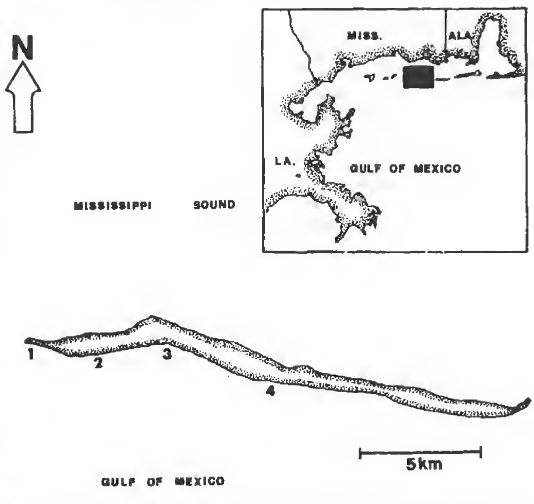


**Figure 1. Chart of Horn Island and vicinity, Jackson County, Mississippi. Four collection stations are indicated.**

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Manuscript received June 9, 1980; accepted August 9, 1980.

rapidly exchanged through the passes. Because of its proximity to the coast, however, the salinity of the outer beaches is affected by seasonal discharges from mainland rivers. During the study period, outer beach salinities on Horn Island ranged from 18.0 ppt in March to 33.0 ppt in July and August.

Four primary collecting stations were established along the windward shore of Horn Island between the western tip and its midpoint (Figure 1). Collections were taken from each station at approximately 5-week intervals between May 1976 and November 1977 (Table 1). In addition, monthly collections were taken between March and September 1976, excluding August, at approximately 4-hour intervals from a single station. On occasion, collections also were taken from locations adjacent to stations 3 and 4. In addition, fishes collected between April and November 1975, at approximately 7-week intervals from undesignated locations along the western half of Horn Island, also were included in the analysis.

Fishes were collected with a 9.1 m seine with 3.2 mm mesh. Seine hauls were made perpendicular to the beach, and within 16 to 18 m from shore. Individual collections at each station consisted of a successive number of seine hauls until no new species were collected (generally ranging between 5 and 9 hauls). A total of 613 seine hauls were made in 112 collections. Fishes collected were identified to species, and their standard length (SL) recorded at 5-mm intervals. Data were grouped by collection for determination of percent occurrence.

## RESULTS

The ichthyofauna collected from the surf zone of Horn Island during the present study were primarily postlarval and juvenile fishes, with only 1.1% of the numbers exceeding 50 mm standard length. Based upon their temporal utilization

**TABLE 1**

**Collection dates for fish taken from the surf zone habitat on the windward shore of Horn Island, Mississippi, between April 1975 and November 1977. Each collection represents a set of seine hauls taken from a specific location.**

| 1975 | | 1976 | | 1977 | |
|---|---|---|---|---|---|
| Date | Number of Collections | Date | Number of Collections | Date | Number of Collections |
| 4/12 | 3 | 3/13 | 6 | 1/22 | 4 |
| 6/21 | 2 | 4/23 | 4 | 3/17 | 5 |
| 8/12 | 3 | 5/28 | 7 | 4/28 | 5 |
| 10/18 | 4 | 6/25 | 11 | 5/27 | 8 |
| | | 7/23 | 8 | 6/27 | 5 |
| | | 8/24 | 5 | 7/23 | 5 |
| | | 9/ 2 | 8 | 9/17 | 4 |
| | | 10/ 1 | 6 | 11/23 | 4 |
| | | 12/ 4 | 5 | | |

of the shallow, inshore habitat, the more abundant juvenile fishes collected could be divided into either resident or migrant categories. According to subjective analysis of length frequency patterns, and to a lesser extent frequency of occurrence, only 6 of 76 species, representing 42.0% of the fishes numerically, were categorized as residents. The greatest number of individuals and species collected were considered migrant fishes; however, the dominant numerical component of this category was represented by only a few species (Table 2).

**TABLE 2.**

**Numbers and percent occurrence of the resident and most abundant migrant fishes collected from the surf zone of Horn Island between April 1975 and November 1977.**

| Species | Number | % Occurrence |
|---|---|---|
| **Resident** | | |
| *Harengula jaguana* | 59,732 | 64.3 |
| *Trachinotus carolinus* | 3,268 | 56.3 |
| *Menticirrhus littoralis* | 1,394 | 67.0 |
| *Menticirrhus americanus* | 272 | 25.9 |
| *Menticirrhus saxatilis* | 116 | 34.8 |
| *Astroscopus y-graecum* | 19 | 9.8 |
| Total | 64,801 | |
| **Migrant** | | |
| *Anchoa lyolepis* | 64,031 | 47.3 |
| *Brevoortia patronus* | 8,848 | 17.9 |
| *Anchoa hepsetus* | 3,751 | 44.6 |
| *Anchoa mitchilli* | 2,953 | 29.5 |
| *Leiostomus xanthurus* | 2,216 | 18.8 |
| *Anchoviella perfasciata* | 1,255 | 21.4 |
| Other species | 6,634 | |
| Total | 89,668 | |

Resident fishes were considered those species which indicated adolescent utilization of the surf zone by a relatively uniform increase in length throughout a given season, and usually exhibited a high frequency of occurrence. Numerically, the dominant resident species collected from Horn Island between 1975 and 1977 was *Harengula jaguana*. A small number of scaled sardine, between 16 and 25 mm, first appeared in the beach area in April 1976 and 1977 (Figure 2). Although recruitment was continual, particularly in 1976, most immigration occurred during two periods within each season. The modal length interval of fish collected in June 1975 was 31 to 35 mm; however, the modal length interval in August 1975 was 21 to 25 mm, indicating a second wave of recruitment. Incidence of two waves in recruitment was more clearly indicated by length frequency data from 1976 and 1977. Fish first appeared in the beach area in early spring, increased in length, and were not well

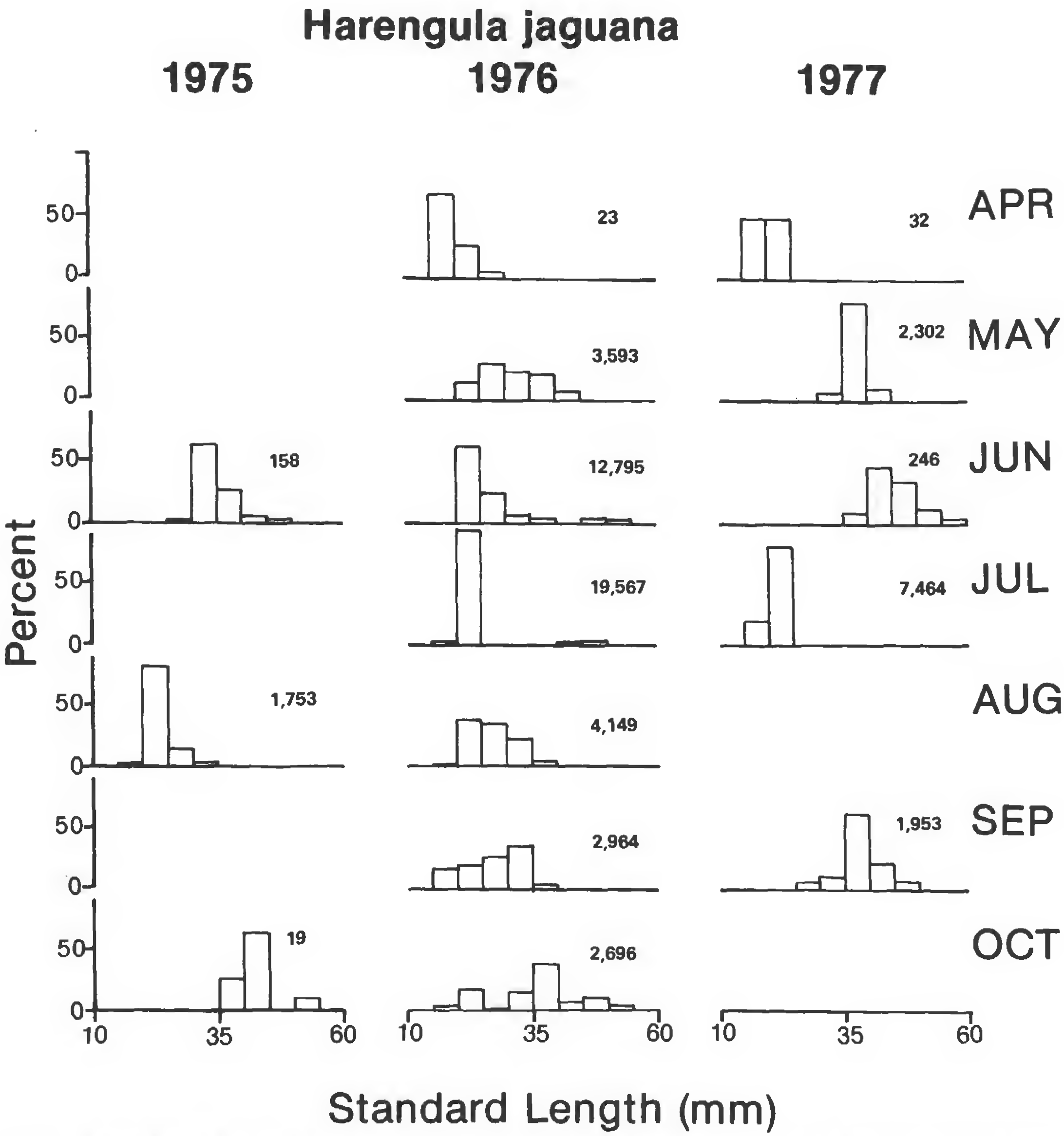


Figure 2. Seasonal length frequency changes and monthly numbers of *Harengula jaguana* collected from the surf zone of Horn Island between April 1975 and September 1977.

represented in beach collections after June. Fish representing the second wave of recruitment appeared in late June and July, and increased in length through early October. Individuals exceeding 50 mm were not well represented in seine collections, which may be attributed to both reduced susceptibility to capture and movement outward from the beach.

*Trachinotus carolinus*, the second most abundant resident, was also first captured from the surf zone in April with most individuals ranging between 16 and 20 mm long (Figure 3). Greatest recruitment of juvenile pompano occurred through the spring of 1975 and 1976, and during both spring and summer of 1977. Length frequencies suggested that growth rates were rapid, with fish spawned in early spring reaching standard length of 80 mm by late June. Fish greater than 80 mm were rarely collected from the surf zone. Although *Menticirrhus littoralis* was only third in abundance among

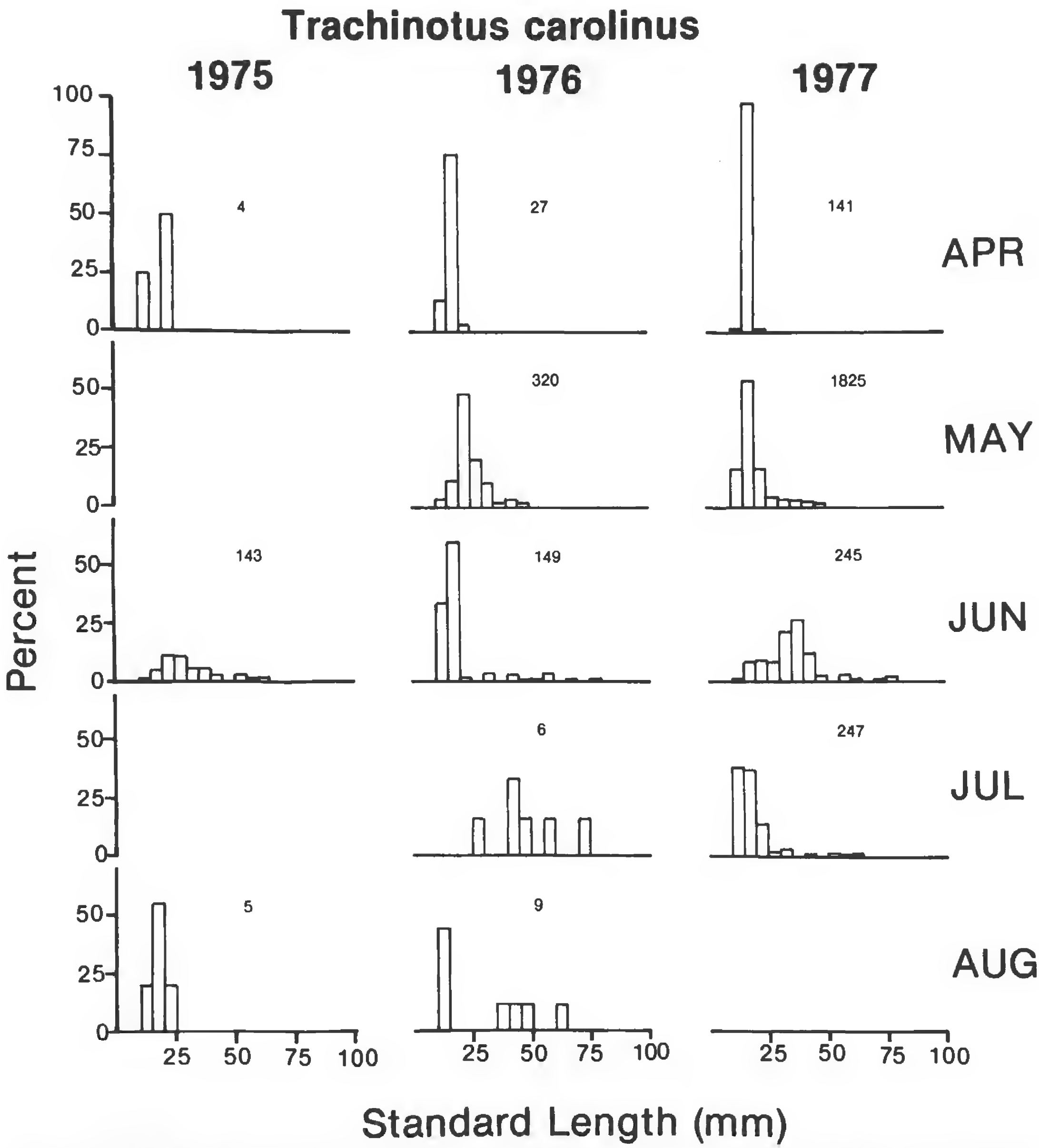


**Figure 3.** Seasonal length frequency changes and monthly numbers of *Trachinotus carolinus* collected from the surf zone of Horn Island between April 1975 and July 1977.

resident fishes, the Gulf kingfish exhibited the highest frequency of occurrence (Table 2). These fish first appeared within the surf zone as larvae, some as small as 8 mm SL. Recruitment of juvenile fishes appeared greatest during the summer months but was observed as early as April and as late as October (Figure 4). In mid-April of 1977, these fish first appeared with a 16- to 20-mm modal length. However, in both 1975 and 1976, larval *M. littoralis* did not appear in the surf zone until after April. Recruitment of juveniles onto the beach continued through July, and also was observed during October in both 1975 and 1976. Immature fish approaching 80 mm were collected by

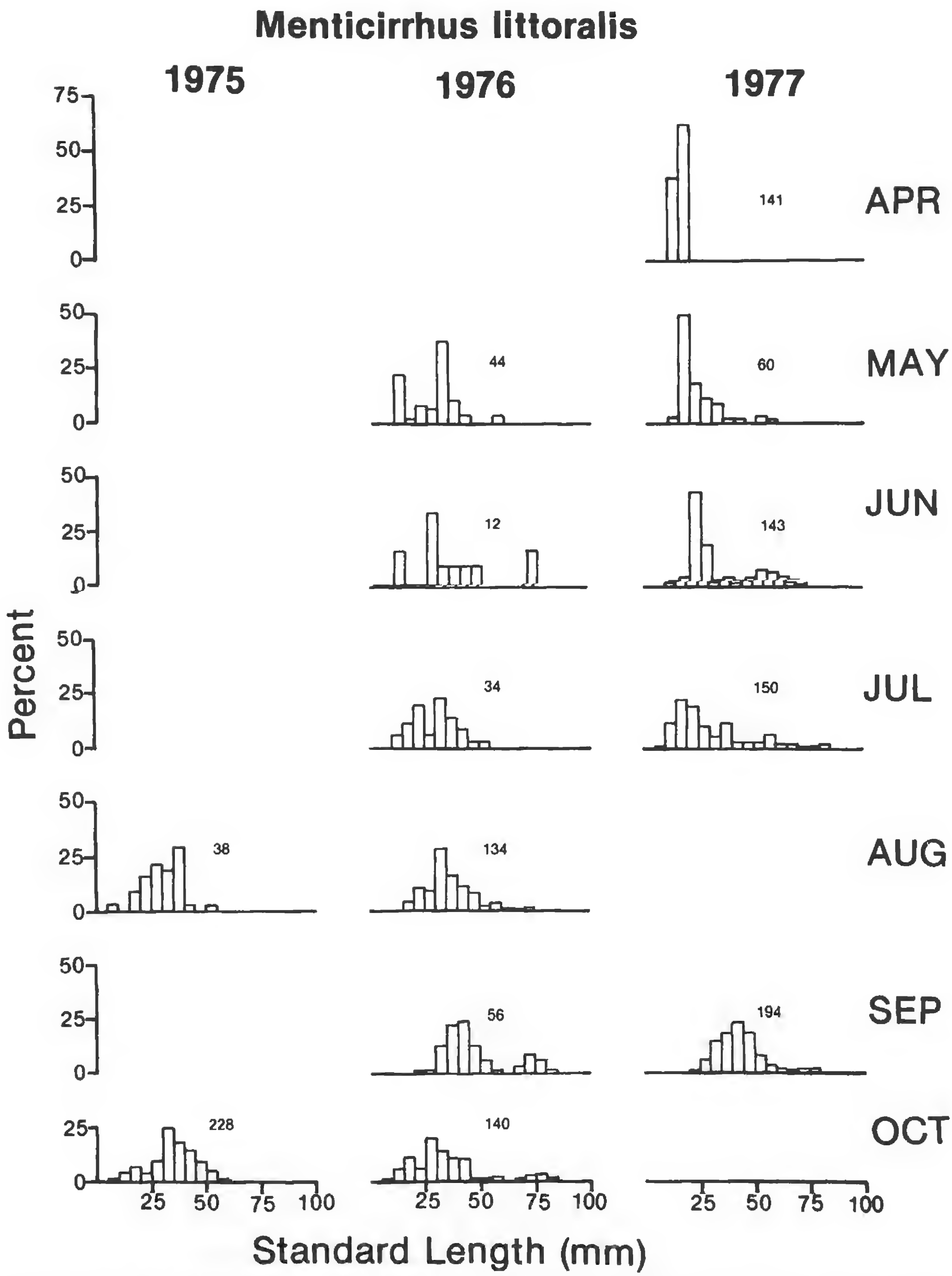


Figure 4. Seasonal length frequency changes and monthly numbers of *Menticirrhus littoralis* collected from the surf zone of Horn Island between April 1975 and September 1977.

the end of August 1976 and June 1977.

Relatively few *Menticirrhus saxatilis* or *M. americanus* were collected during this study. Small *M. saxatilis*, 6 to 10 mm SL, first appeared in April with fewer individuals of increasing length collected through October. Increases in lengths of fish during a season were similar to *M. littoralis* with a few individuals between 96 and 100 mm collected in June 1977. *Menticirrhus americanus* was first collected in May. Few postlarval fish were captured with only three specimens collected under 16 mm SL. As were its congeners, *M. americanus* also was collected through October with fish reaching 91 to 95 mm as early as June.

The least abundant resident collected was *Astrocopus y-graecum*. The relatively few number of fish captured can be attributed to both low density and their mode of concealment within the sand. Juveniles, 11 to 20 mm SL, were collected most often in the surf zone during the months of November and December. Isolated subadults and adults were collected between May and July 1976, and April and July 1977.

Migrant juvenile fishes were considered those species which utilize or pass into the surf zone habitat for only a brief time. They did not exhibit uniform increases in length during the periods in which they were collected from the exposed inshore habitat. This category constituted 58.0% of the individuals, and by far, the greatest number of species (70) collected from Horn Island. Migrants could be further subdivided into either estuarine or marine categories. Estuarine migrants represented denatant (*sensu* Cushing 1975) immigrants, which were spawned offshore and moved through the barrier island passes into Mississippi Sound, and fishes straying from estuaries. The former group was represented primarily by immature *Brevoortia patronus, Leiostomus xanthurus, Lagodon rhomboides, Mugil cephalus,* and *Eucinostomus* sp. The first four species were collected primarily during the winter months and composed 97.9% of the fishes collected between January and March in 1976 and 1977. Estuarine strays were most common during warmer months (Modde and Ross 1980), and were primarily represented by *Anchoa hepsetus* and *A. mitchilli*.

Marine migrants were represented primarily by immature fishes migrating or straying through marine waters adjacent to Horn Island. Although most species were observed irregularly in low numbers, several species occurred consistently throughout the study. Most marine migrants appeared during the summer months; however, *Sphyraena borealis* and *Pomatomus saltatrix* were collected only between March and May.

The marine migrant category was dominated numerically by *Anchoa lyolepis* and included species such as *Anchoviella perfasciata* and *Sardinella anchovia*. The dusky anchovy was collected consistently in large numbers within the surf zone between May and September 1976. In 1975, large numbers of *A. lyolepis* were collected only in August, while in 1977, fish were abundant in May and July although no collection was taken in August. Length frequency data indicate that no increase in length intervals occurred during the study, suggesting a continual influx and rapid departure of juvenile fish (Figure 5). The greatest number of individuals was represented by late larvae and newly transformed juveniles. Transformation occurred between 28 and 30 mm SL.

## DISCUSSION

Immature fishes constituted the dominant numerical component of the ichthyofauna collected from the surf zone of Horn Island, Mississippi. The relative abundance of juvenile fishes within the exposed inshore habitat of the Gulf of Mexico has also been reported by Gunter (1958), Springer and Woodburn (1960), and Naughton and Saloman (1978). Among the fishes collected from Horn Island only 7.9% of the species, yet nearly half of the numbers, resided seasonally within the surf habitat. In the previously cited studies, the dominant numerical component of the surf zone ichthyofauna consisted of residents, primarily *Harengula jaguana*. Surprisingly, *Anchoa lyolepis*, the most abundant species collected from Horn Island, was collected only occasionally by Gunter (1958) and Naughton and Saloman (1978), and was not mentioned by McFarland (1963b) or by Springer and Woodburn (1960). Christmas and Waller (1973) reported capturing large *A. lyolepis* (nasuta) within Mississippi Sound but stated that over several years of observation, the dusky anchovy occurred only in the summer and fall months and never was abundant in Gulf inshore waters. Because *A. lyolepis* were collected primarily as small postlarvae in the present study and were most common within the surf zone habitat in the early light hours (Modde and Ross 1980), this species may not have been accessible to previous investigations in the northern Gulf in which larger mesh seines were used during the diurnal hours.

Residency within the exposed inshore habitat for both mature (McFarland 1963b) and immature (Gunter 1958) fishes has been observed to be limited primarily to the spring and summer months. In this respect, the nursery function of the surf zone varies from the estuarine areas. While utilization of estuaries by immature residents occurs through the cold-temperature months (Gunter 1945, Livingston 1976), only *Astroscopus y-graecum*, in relatively low numbers, resided within the exposed beach habitat of Horn Island during the winter period. Recruitment of most species residing within the Horn Island surf zone was observed first in April. Although changes in length frequency varied among species, larger individuals of the three more abundant species, *H. jaguana, T. carolinus,* and *M. littoralis,* were no longer collected after approximately 3 months following this initial appearance within the inshore habitat. Bellinger and Avault (1970), reporting growth rates of *T. carolinus* collected from the Louisiana coast, indicated that pompano utilized the surf zone for only 2 1/2 to 3 months before moving off the beach into deeper water. Individuals of the three more abundant species in the present study, representing the

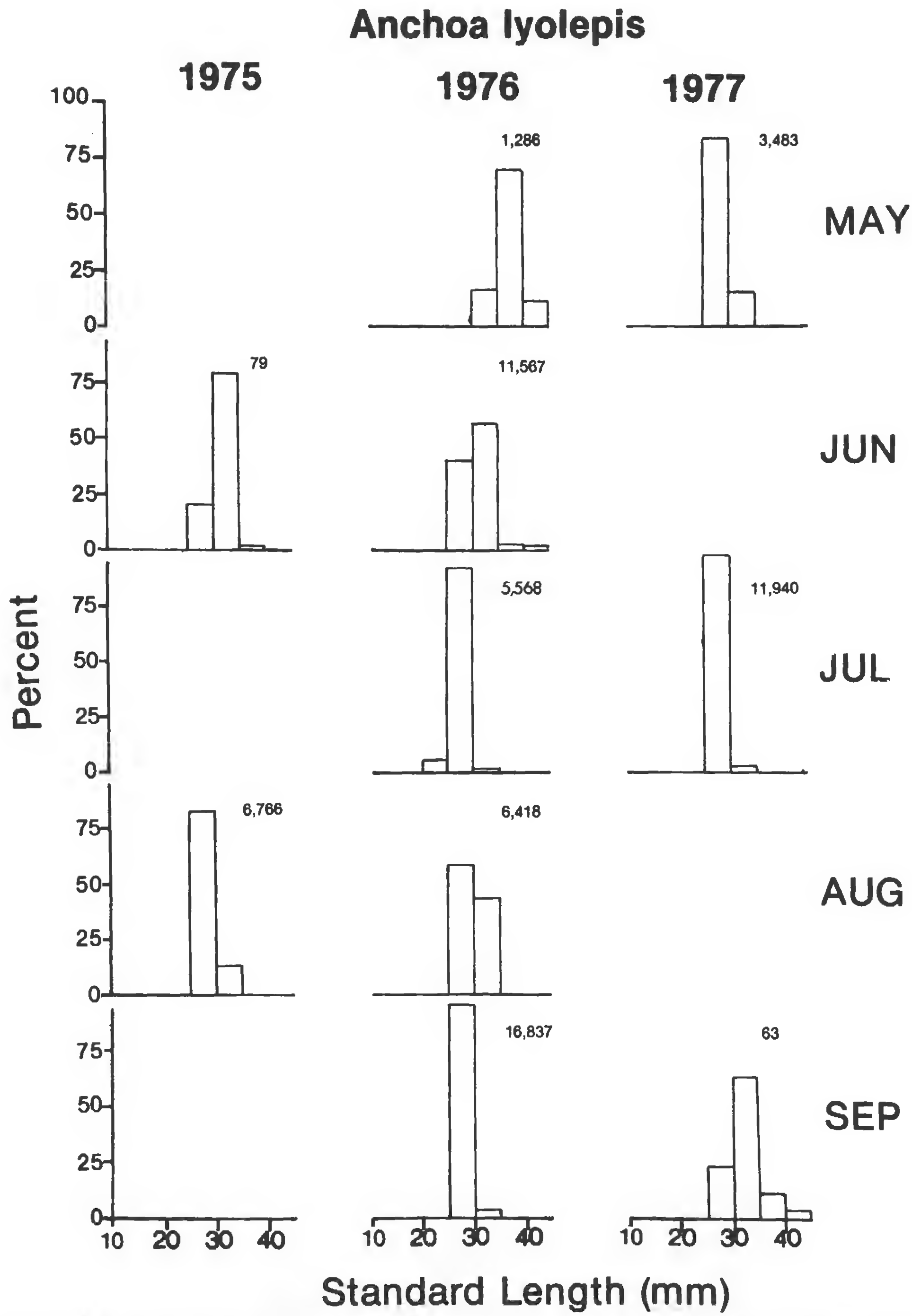


Figure 5. Seasonal length frequency changes and monthly numbers of *Anchoa lyolepis* collected from the surf zone of Horn Island between April 1975 and September 1977.

greatest portion of immature resident fishes occupying the surf zone of Horn Island, also appeared to utilize this habitat as a nursery for approximately 3 months.

Although recruitment of *T. carolinus* and *M. littoralis* into the beach area appeared intermittent, *H. jaguana* exhibited two distinct waves of recruitment. Christmas and Waller (1973) also have observed a bimodal length frequency of *H. jaguana* collected during a single season from Mississippi Sound. Gunter (1945, 1958) reported two peaks in recruitment of juvenile *H. jaguana* onto Mustang Island, TX, beaches, and suggested that this species exhibited two spawning periods: one in spring and one in late summer. However, length frequency data of *H. jaguana* collected from Florida suggested only a single peak in recruitment into the beach habitat (Springer and Woodburn 1960, Roessler 1970), as did larval abundance data reported from the Texas coast (Hoese 1965). Houde (1977) reported that spawning did not occur in great concentrations in the eastern Gulf of Mexico and suggested that it may occur twice, intermittently, within individuals during the season.

Although many estuarine fishes either strayed or actively moved into the adjacent higher-salinity beach habitat, the greatest number of estuarine migrants was represented by winter denatant postlarvae. The presence of these migrating larvae represented a temporary concentration along the seaward side of the island associated with the movement of fishes through the island passes into Mississippi Sound. Conversely, most marine migrants, while representing the greatest number of species, were the most common during the summer. Marine and estuarine categories roughly corresponded with the two migrant categories suggested by Warfel and Merriman (1944), regularly occurring and stray species.

Most marine migrant fishes did not appear within the surf zone on a regular basis; however, the dominant numerical component of this category, *Anchoa lyolepis* and *Anchoviella perfasciata*, occurred consistently throughout the study. Length frequency patterns of *A. lyolepis* indicated that a continual influx and departure of individuals from the surf zone occurred. In addition, Modde and Ross (1980) reported that *A. lyolepis* exhibited a distinct daily activity pattern. The consistently high number of fishes collected which exhibited a distinct daily activity pattern suggested that this fish utilized the exposed inshore habitat as some form of refuge or orientation site.

The present study indicates that the surf zone habitat of an exposed sand beach represents a significant spatial resource to the early life stages of certain fishes within the northern Gulf of Mexico. Nearly half of the fishes collected from the surf zone of Horn Island used this area as a residence. In addition, this habitat appeared to attract a large number of immature migrant fish which may briefly utilize this environment either as a refuge or an orientation site.

## ACKNOWLEDGMENTS

The material presented represents a portion of a dissertation submitted to the Biology Department of the University of Southern Mississippi. Sincere appreciation is extended to Stephen T. Ross who initiated the investigation and offered helpful criticism through all phases of my study. I am also indebted to Kathleen Clark and John Baker for their consistent willingness to aid in field collections. Thanks are given to committee members B. J. Grantham, F. G. Howell, J. W. Cliburn, and A. G. Fish. I also thank Robert Hastings who reviewed the initial manuscript and offered helpful suggestions. Funding was provided by two Sigma Xi research grants-in-aid.

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# Gulf Research Reports

Volume 6 | Issue 4

January 1980


# Observations on the Genus *Vaucheria* (Xanthophyceae, Vaucheriales) from the Gulf of Mexico


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*Gulf Research Reports*, Vol. 6, No. 4, 387–391, 1980.

# OBSERVATIONS ON THE GENUS *VAUCHERIA* (XANTHOPHYCEAE, VAUCHERIALES) FROM THE GULF OF MEXICO

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*ABSTRACT* Investigations of algal mats from several locations along the Gulf of Mexico from Cameron Parish, Louisiana, to Manatee County, Florida, were conducted from February 1979 to February 1980. Habitat preference, distribution, and morphology are reported herein for nine species and one variety of *Vaucheria* de Candolle. Five taxa–*V. arcassionensis, V. aversa, V. coronata, V. prolifera* var. *reticulospora*, and *V. pseudogeminata*–are first reports for the Gulf of Mexico coastal region. *Vaucheria velutina* (=*V. thuretii*), the most abundant taxon identified in the region, is common in diverse habitats. *Vaucheria prolifera* var. *reticulospora* is reported for the first time in North America from coastal Mississippi.

## INTRODUCTION

Recent investigations of algae from coastal regions of the Gulf of Mexico indicate that species of *Vaucheria* de Candolle are abundant throughout the winter months (Pecora 1976, 1977, 1978). These studies reveal a diverse but seasonal assemblage of *Vaucheria* species in the region. Other investigations, including those of Humm and Caylor (1957), Humm and Taylor (1961), Humm and Hamm (1976), and Gallagher and Humm (1980), also report species of *Vaucheria* from diverse habitats within the region. This report is based on 1979 and 1980 field and laboratory studies of species of *Vaucheria* in the coastal region of the Gulf of Mexico from Cameron Parish, Louisiana, to Coquina Beach, Manatee County, Florida. Identification of *Vaucheria* species was enhanced in subsequent laboratory studies since oogonia and antheridia are normally produced when algal filaments lacking sex cells are incubated under controlled environmental conditions in the laboratory. Nine species and one variety of *Vaucheria* are reported herein, of which *V. arcassionensis, V. aversa, V. coronata, V. prolifera* var. *reticulospora*, and *V. pseudogeminata* are new to the Gulf of Mexico region. *V. adela* is newly reported from Louisiana, and *V. erythrospora* is newly reported from Florida. I report herein the recently proposed *V. prolifera* var. *reticulospora* (Rieth 1978) for the first time in North America from Hancock County, Mississippi.

## MATERIALS AND METHODS

Samples of algal mats were taken from various sites along the Gulf of Mexico from southwestern Louisiana to central Florida. Salinities were measured with an American Optical refractometer. Procedures for collection, maintenance of algal material, and documentation are as reported previously (Pecora 1976, 1977).

## OBSERVATIONS AND DISCUSSION

Taxa are arranged alphabetically. Names preceded by an asterisk have not been reported previously from the Gulf of Mexico region. Size, temperature, and salinity determinations not indicating a range of variation are means.

### *Vaucheria adela* Ott and Hommersand 1974 (Figure 1)

Filaments to 35 μm in diameter, branched; monoecious; androphores terminal; antheridia pedicellate, hooked or coiled, lanceolate, with a single terminal pore, one to several per androphore; oogonia solitary on filaments, subsessile, oval to obliquely ovoid, with a small distal vertical beak; oospores almost filling the oogonium, bearing a reddish-brown spot at maturity.

*V. adela* was collected on March 13, 1979, on moist soil of a *Spartina patens* (Ait.) Mull. marsh along Louisiana Route 1, Lafourche Parish. It was a component of large algal mats (ca 0.3 to 1.2 $m^2$) in open, nonshaded areas of the marsh. The temperature of standing water was 21°C, and the salinity averaged 6.0 ppt. Sexual cells were observed when collected and filaments of *V. erythrospora, V. repens*, and *V. velutina* were identified after portions of algal mats were incubated in the laboratory for four days. The Louisiana plants are similar in size and morphology to those collected at the type locality in North Carolina (Ott and Hommersand 1974), and from a *Juncus roemerianus* Scheele marsh on Marsh Island in St. Louis Bay, Mississippi (Pecora 1978). This is the first report of *V. adela* from Louisiana, and the second of this alga in North America exclusive of the type locality.

### **Vaucheria arcassionensis* Dangeard 1939 (Figure 2)

Filaments 58 to 94 μm in diameter, branched; monoecious, sex cells usually borne in bisexual pairs, antheridia occasionally not adjacent to an oogonium, antheridia, pedicellate, 29 to 36 x 60 to 120 μm, tubular coiled, with one terminal pore; oogonia 79 to 108 x 108 to 161 μm, frequently on a short pedicel, rarely sessile, ovoid; oospores elliptical-ovate, filling most of the oogonium, with a thick (4.8 μm) wall.

*V. arcassionensis* was collected on December 17, 1979, on soil of a *Juncus roemerianus* marsh at Live Oak Point, St. Marks State Park, Wakulla County, Florida. It occurred in exposed areas at the edge of the marsh, and was mixed

Manuscript received August 1, 1980; accepted August 22, 1980.

with filaments of *Cladophora* sp. and *Dichotomosiphon tuberosus* (A.Br.) Ernst. The salinity and temperature of soil water were 25 ppt and 14°C, respectively. Filaments were sterile when collected but produced mature sex cells after 9 days of incubation in the laboratory.

*V. arcassionensis* was described from France (Dangeard 1939), and has subsequently been identified in the United States from New England (Taylor 1937, Blum and Conover 1953, Webber 1968), and from North Carolina (Ott and Hommersand 1974). This was the most abundant species of *Vaucheria* identified from coastal North Carolina (Ott and Hommersand 1974); however, my studies conducted largely since 1974, indicate that *V. velutina* (*thuretii*) is the most abundant *Vaucheria* species in the Gulf of Mexico region. This first report of *V. arcassionensis* in the Gulf of Mexico region extends its recorded range from North Carolina to Florida.

****Vaucheria aversa* Hassall 1843 (Figure 3)**

Filaments 41 to 96 μm in diameter; monoecious; oogonia single or in short series, 82 to 113 X 96 to 132 μm, subspherical with a deflexed beak which contains a large (16.2 μm) pore; oospores spherical to ovoid, 87 μm in diameter, not filling the oogonium; antheridia, 22 to 36 X 48 to 84 μm, sessile or borne on a short pedicel, cylindrical, tapering slightly to a single terminal pore which is directed toward an oogonium.

*V. aversa* was collected on February 17, 1979, on moist soil from a freshwater marsh adjacent to Little Bayou, Vermilion Parish, Louisiana, and on January 26, 1980, on hummocks in a freshwater marsh in Buccaneer State Park, Hancock County, Mississippi. In both locations *V. aversa* was found with other common freshwater algae such as *Spirogyra* sp. and *V. racemosa.* Plants collected at both locations contained only the subspherical oogonia; the erect or oblique short-fusiform oogonia (Blum 1972) were not observed. *V. aversa* has been reported in freshwater areas of the eastern and midwestern United States (Collins 1928, Koch 1951, Blum 1972), and is widely distributed outside of North America. This report of *V. aversa* is the first for both Louisiana and Mississippi, as well as for the Gulf of Mexico coastal region.

****Vaucheria coronata* Nordstedt 1879 (Figure 4)**

Vegetative filaments 46 to 62 μm in diameter; monoecious, bisexual pairs of sex cells on short (43 to 97 μm) branches or oogonia and antheridia on separate short branches; oogonia ovoid, 82 to 105 X 87 to 158 μm, opening by several tubular papillae forming a corona; oospores spherical, 104 μm in diameter, not filling the oogonium, with a prominent central red spot when mature; antheridia containing a lateral discharge pore 36 to 46 X 48 to 65 μm, cylindric, separated from the branch by a small empty space, occassionally two antheridia on a single fruiting branch.

*V. coronata* was collected on February 28, 1979, on soil of a recently burned *Spartina patens* marsh along Louisiana Route 57, Terrebonne Parish, Louisiana. It occurred in small bright-green algal mats in open areas along with *V. dillwynii, V. erythrospora,* and *V. synandra.* Although sexual when collected, filaments of *V. coronata* contained neither intercalary antheridia nor akinetes (Simons 1974). The salinity and temperature of standing water at the collection site were 3.0 ppt and 17°C, respectively.

*V. coronata* is a commonly reported alga from salt marshes in northern Europe. Nienhuis and Simons (1971), DeJonge (1976), and Wilkinson (1975) all report *V. coronata* as common in coastal areas. However, in the United States, the recorded distribution of this alga was limited previously to the eastern Atlantic coast (Collins 1928, Blum and Conover 1953, Ott and Hommersand 1974, Bird et al. 1976). I report herein *V. coronata* for the first time from Louisiana, and from the Gulf of Mexico coastal region.

***Vaucheria erythrospora* Christensen 1956 (Figure 5)**

Filaments 26 to 43 μm in diameter; monoecious; antheridia 19 μm in diameter on short pedicels, coiled, circinate, with a single terminal pore; oogonia at the end of a lateral branch (to 600 μm), solitary, 58 to 72 X 67 to 82 μm, ovoid to reniform, dehiscent, with a prominent beak; oospore not filling the oogonium, with a red-brown wall and a reddish central spot when mature.

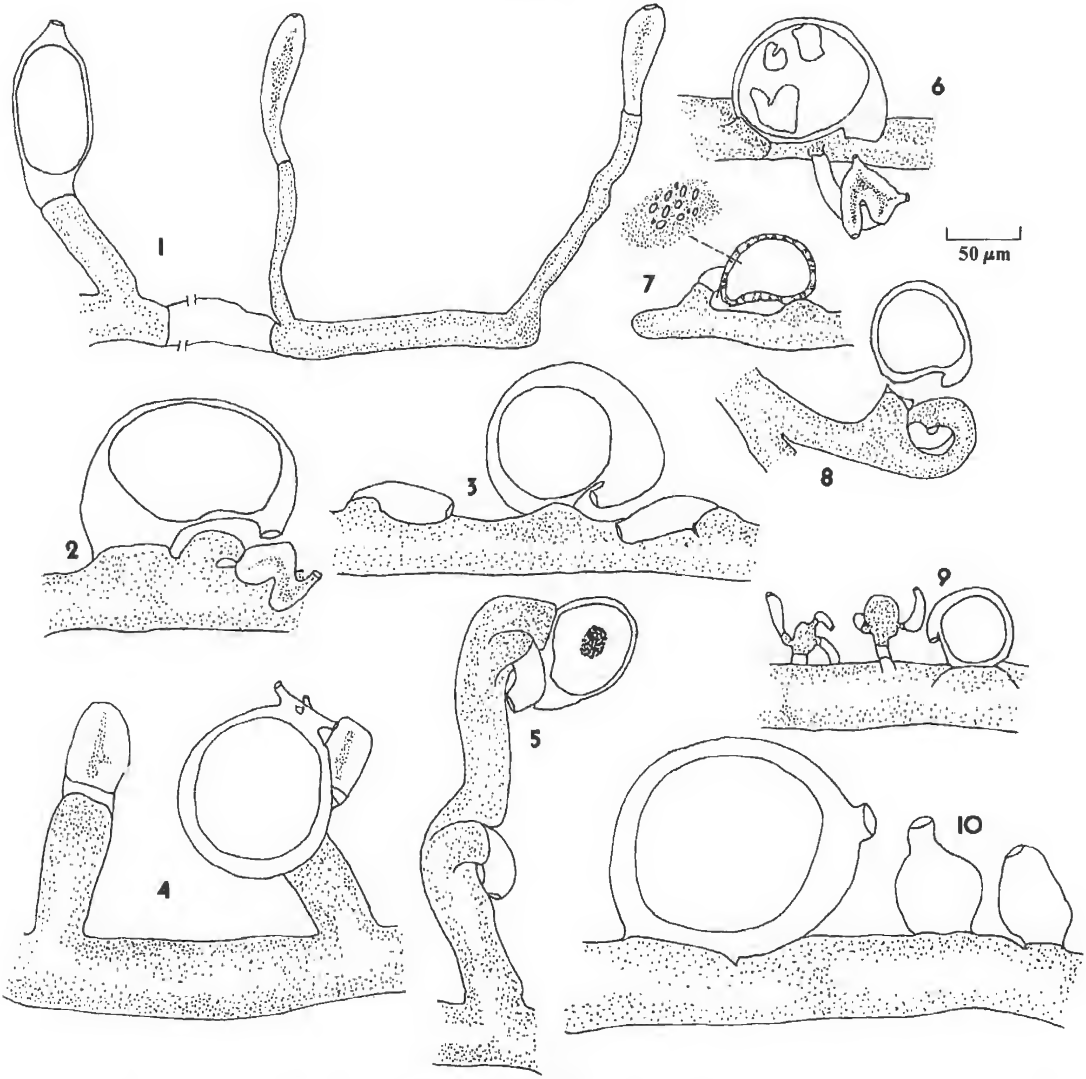
*V. erythrospora* was collected on December 16, 1979, on sand in a field of the grass *Dactyloctenium aegyptium* (L.) Beauv. at Coquina Beach, Manatee County, Florida. Plants were sexual when collected. I have collected *V. erythrospora* from various locations and habitats in Louisiana and Texas where the salinity ranged from 1.0 to 25.0 ppt (Pecora 1977). This first report of *V. erythrospora* in Florida extends its range from Louisiana in the Gulf of Mexico coastal region. Prior to my 1977 report, the southern limit of the distribution of *V. erythrospora* was in North Carolina (Ott and Hommersand 1974).

***Vaucheria nasuta* Taylor and Bernatowicz 1952 (Figure 6)**

Filaments to 51 μm in diameter; monoecious; antheridia, usually associated with an oogonium, one to several, separated from the filament by short empty cells, tubular, curved, with a terminal and one to several lateral pores; oogonia sessile, with a large deflexed beak; oospores spherical, containing plate-like lipid bodies, almost filling the oogonium.

*V. nasuta* was collected on March 13, 1979, on dry soil from open areas of a *Spartina patens* and *Salicornia* sp. marsh adjacent to Louisiana Route 1, Lafourche Parish, Louisiana. Small (ca 10 $cm^2$) mats of *Vaucheria* species were confined to elevated dry areas of the marsh. Plants were not sexual when collected but produced abundant sex cells after 12 days of incubation in the laboratory.

This species is well known in the United States (see Pecora 1978). Along the Gulf coast, this alga was reported from the




Figures 1–10. *Vaucheria* species from the Gulf of Mexico. Bar represents 50 μm. 1. *V. adela*–Androphore with two antheridia and a portion of a filament with an oogonium. 2. *V. arcassionensis*–Filament bearing an oogonium and antheridium. 3. *V. aversa*–Filament bearing an oogonium and two antheridia. 4. *V. coronata*–Filament bearing an oogonium and two antheridia. 5. *V. erythrospora*–Bisexual fruiting branch. 6. *V. nasuta*–Filament bearing an oogonium and antheridium. 7. *V. prolifera* var. *reticulospora*–Filament bearing an oogonium and antheridium. 8. *V. pseudogeminata*–Bisexual fruiting branch with a dehiscent oogonium. 9. *V. synandra*–Filament bearing an oogonium and two androphores each bearing antheridia. 10. *V. velutina*–Filament bearing an oogonium and two antheridia.

Calcasieu River, Louisiana (Kapraun 1974), and from a *Spartina patens* marsh along the Aransas River, Texas (Pecora 1978). I have identified several other possible collections of *V. nasuta* which did not develop diagnostic features adequate for positive identification. The infrequent reports of this taxon may result from its brief occurrence in the sexual condition.

******Vaucheria prolifera*** **Dangeard var.** ***reticulospora*** **Rieth 1978 (Figure 7)**

Vegetative filaments 24 to 41 μm in diameter; monoecious, sex cells in bisexual pairs; oogonia 41 to 48 × 58 to 91 μm, subterminal, sessile, ovoid; antheridia terminal, saccate, to 35 μm in length; oospore filling the oogonium

except for the beak, with a prominent central red-brown spot and reticulate outer wall.

This *Vaucheria* species was collected on January 26, 1980, on compacted plant debris at the edge of a *Juncus roemerianus* marsh, Buccaneer State Park, Hancock County, Mississippi. The site, at the time of collection, was dry and contained many small (ca 5 to 9 $cm^2$), bright-green algal mats. Temperature of standing water in the adjacent marsh was 15°C, and the water had a salinity of 9.5 ppt. Algal mats grew at elevations above the normal high water level of the adjacent marsh. The freshwater species *V. racemosa* and several species of desmids also were identified from the same location.

Since my 1977 report of *V. prolifera* var. *prolifera* from a *Phragmites communis* Trin. marsh, I have identified the typical form of this alga from several locations in Louisiana during the winter months of 1978 and 1979. These collections were made from freshwater and from low-salinity (4.0 ppt) habitats. *V. prolifera* var. *reticulospora* was proposed by Rieth in 1978 to include plants with reticulate-foveate oospore walls. The Mississippi plants compare favorably in dimension and morphology to those at the type location except that the oogonia of the Mississippi plants were smaller and neither aplanospores nor aplanosporangia were observed. I report herein the first collection of *V. prolifera* var. *reticulospora* from a site other than the type location in the Harz Mountains, Germany.

### **Vaucheria pseudogeminata* Dangeard 1939 (Figure 8)

Vegetative filaments 26 to 41 μm in diameter; monoecious, sex cells in bisexual pairs on pedicels to 460 μm long; antheridia 14 to 19 X 36 to 48 μm, circinate, partially coiled; oogonia 63 to 74 X 72 to 96 μm, one per branch, reniform, with a conical beak, 21 μm at its base and tapering to a 10-μm pore; oospores filling the oogonia except for beak, with a central red spot and a thick wall when mature.

*V. pseudogeminata* was collected on December 28, 1978, January 25, February 23 and March 20, 1979, from the exposed walls of a branch channel of the Intracoastal Canal at Louisiana Route 318, St. Mary Parish, Louisiana; on March 29, 1979, on well-shaded soil at the base of black mangrove (*Avicennia germinans* [L.] L.), Bayou Fouchon, with a salinity of 27.0 ppt; and on January 26, 1980, from hummocks in a freshwater marsh area of Buccaneer State Park, Hancock County, Mississippi.

*V. pseudogeminata* occurred in small, bright-green feltlike patches (ca 2 to 12 $cm^2$). It was associated with *V. prolifera* var. *prolifera* at the Intracoastal Canal site, and with *V. erythrospora*, *V. nasuta*, and *V. synandra* at Bayou Fouchon. *V. aversa* and freshwater racemose species of *Vaucheria* were identified in collections made at Buccaneer State Park. Although the water at Bayou Fouchon had a salinity of 26.0 to 27.0 ppt, *V. pseudogeminata* grew at an elevation that normally would be out of the tidal influence except in times of extremely high water. Similarly at the Intracoastal Canal, this species of *Vaucheria* grew at 1.0 to 1.3 m above the normal high-water mark.

This alga is commonly reported in Europe (e.g., Christensen 1969, Simons 1974, Rieth 1975); and in the United States, it is known from a California salt marsh (Blum 1971) and from Florida (Blum 1953). These are the first reports of *V. pseudogeminata* from Mississippi and Louisiana.

### *Vaucheria synandra* Woronin 1869 (Figure 9)

Filaments 65 to 94 μm in diameter, branched; monoecious; androphores, 57 X 91 μm, attached to the filament by a small empty cell; antheridia, one to several, hooked, sessile on the androphore, opening by a terminal pore; oogonia 91 to 132 X 113 to 156 μm, solitary, sessile, with a conspicuous beak; oospore, oval, filling the oogonium except for the beak, wall punctate.

*V. synandra* was collected on February 28, 1979, from a recently burned *Spartina patens* marsh adjacent to Louisiana Route 57, Terrebonne Parish, Louisiana; and on March 13, 1979, on soil at the base of black mangrove along Bayou Fouchon, Lafourche Parish, Louisiana. The salinity and temperature at the Terrebonne site were 2.0 to 3.0 ppt and 17°C, respectively, whereas values of 26.0 to 27.0 ppt and 20°C, respectively, were recorded at Bayou Fouchon. *V. minuta*?, *V. nasuta*, and *V. pseudogeminata* were identified in soil samples from Lafourche Parish, and *V. dillwynii*, *V. erythrospora*, and *V. coronata* were identified from Terrebonne Parish.

This is the first report of *V. synandra* in the United States since my 1976 report, which added this taxon to the North American algal flora. The present study indicates that *V. synandra* is characteristic of low-salinity habitats as well as habitats that are frequently flooded with brackish water.

### *Vaucheria velutina* C. Agardh 1824 (*V. thuretii* Woronin 1869) (Figure 10)

Vegetative filaments to 71 μm in diameter; monoecious; oogonia single or in pairs, sessile, obovoid, antheridia, one to several, erect, sessile on the filament in the vicinity of the oogonia; oospore not filling the oogonium, subspherical.

*V. velutina*, the earlier legitimate name for *V. thuretii* (Christensen 1973), the most common species of *Vaucheria* in the Gulf of Mexico coastal area, was collected seven times from February 28, 1979, to February 10, 1980. In Louisiana, *V. velutina* was identified on February 28, 1979 on mud in open areas of a *Juncus roemerianus* marsh adjacent to Petite Caillou Bayou, Terrebonne Parish, where the salinity ranged from 4.0 to 9.0 ppt; on March 13, 1979, from compacted sand at the edge of a tidal pool ca 15 m from the beach, Lafourche Parish, where the salinity was 27.0 ppt; on March 13, 1979, from an exposed mud flat in a *Juncus roemerianus* marsh at the Leeville Bridge, Lafourche Parish, with a salinity of 14.0 ppt; and on February 10, 1980, on extensive mud flats at Josephs Harbor, Cameron Parish, with a salinity of 6.5 ppt. In Hancock County, Mississippi, this alga

was collected on January 26, 1980, in exposed mud of a *Spartina patens* marsh on Mississippi Sound adjacent to Buccaneer State Park with a salinity of 2.0 ppt; on January 26, 1980, in mud of a *Juncus roemerianus* marsh near Buccaneer State Park with a salinity of 9.0 ppt; and on January 26, 1980, from dry soil of a recently burned *Juncus roemerianus* and *Distichlis spicata* (L.) Green marsh along Bayside Drive, adjacent to Mississippi Sound.

This report of *V. velutina* from Louisiana and Mississippi supports my recent report (1977) that *V. velutina* (*thuretii*) is the most abundant *Vaucheria* species in the northern Gulf coast region. Plants from four collections were sexual when collected, and plants from three collections produced sex cells after 4 to 14 days incubation in the laboratory. The presence of sex cells in field material could not be correlated to either salinity, which ranged from 2.0 to 27.0 ppt, or water temperature, which ranged from 9 to 24°C. All my collections of *V. velutina* from 1976 to the present were made from December to April. Subsequent incubation of sterile filaments collected during other months failed to produce sexual filaments of *V. velutina*. Along the northeastern Atlantic United States and Canadian coasts, *V. velutina* was identified each month except February (Blum 1971). Similarly Ralph (1977) identified *V. velutina* from salt marshes, pannes, and pools from June to October in coastal Delaware. Elsewhere in the United States, *V. arcassionensis* was the dominant species of *Vaucheria* in North Carolina (Ott and Hommersand 1974), while *V. litorea* was dominant in the winter and spring in Nova Scotia (Bird et al. 1976).

In the Netherlands, *V. velutina* is often the dominant species of *Vaucheria* during the summer months in brackish-water habitats (Simons and Vroman 1973, Nienhuis and Simons 1971, Simons 1975). Extensive mats were formed as the result of prolific aplanospore production (Nienhuis and Simons 1971, Simons 1975). In the cooler months from approximately November to April, *V. arcassionensis* (Simons and Vroman 1973), *V. intermedia* and *V. coronata* (Nienhuis and Simons 1971), and *V. subsimplex* (Simons 1975) were the dominant or subdominant species of *Vaucheria* identified.

## ACKNOWLEDGMENTS

I thank T. D. Bishop, C. T. Hackney, M. W. LaSalle, and J. W. Martin for assistance with field work. This material is based on work supported by the National Science Foundation under Grant No. DEB–77–254400, and funds for faculty research from the University of Southwestern Louisiana.

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Gulf Research Reports

Volume 6 | Issue 4

1980

# Origins and Effects of *Spartina* Wrack in a Virginia Salt Marsh

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DOI: 10.18785/grr.0604.07

*Gulf Research Reports*, Vol. 6, No. 4, 393–401, 1980.

# ORIGIN AND EFFECTS OF *SPARTINA* WRACK IN A VIRGINIA SALT MARSH

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*ABSTRACT* Movements of mats of tidal wrack (dead *Spartina alterniflora*) and impacts of the wrack were followed in color infrared aerial photographs of a sloping foreshore salt marsh on Wallops Island, Virginia. Tidal wrack may be stranded in high marsh, where it decomposes, or it may be temporarily stranded at lower elevations. The wrack kills underlying *Spartina alterniflora* in low marsh and in the transition zone from low to high marsh. Wrack is the major cause of devegetated areas within the marsh, but these areas eventually revegetate, and do not evolve into pans. There are substantial short-term reductions in *S. alterniflora* marsh productivity. Other effects of wrack are discussed.

## INTRODUCTION

Tidal wrack consists of dead plant material which forms mats that are rafted about by winds, tides, and currents (Warming 1904, Harshhberger 1916, Nichols 1920, Conard 1935, Miller and Egler 1950, Kurz and Wagner 1957, Ranwell 1961, Teal 1962, Squires and Good 1974, McCaffrey 1976). In salt marshes of the eastern United States, wrack is mostly woody stems of tall growth form cordgrass, *Spartina alterniflora* (Teal 1962, Nadeau 1972, Squires and Good 1974), but in some areas eelgrass, *Zostera marina*, predominates (Kurz and Wagner 1957, Godfrey and Godfrey 1975).

Typically, thick floating mats are produced by winter wave- and ice-scouring of standing dead vegetation. These mats are often stranded in marshes by high tides. For wrack in marshes, the underlying soil surface replaces the estuary as the site of decomposition (Squires and Good 1974). Litterbag decomposition studies demonstrate that *Spartina* may take more than a year to decompose (Burkholder 1956, Burkholder and Bornside 1957, de la Cruz 1965). Microcommunities of amphipods, isopods, earwigs, and *Melampus* snails inhabit decomposing wrack (Wass and Wright 1969).

Where mats of tidal wrack remain in marshes for some time, the vegetation underneath often dies back from compaction and smothering (Warming 1904, Harshberger 1916, Nichols 1920, Conard 1935, Miller and Egler 1950, Kurz and Wagner 1957, Ranwell 1961, Stalter 1968, McCaffrey 1976). The diebacks leave devegetated patches of "secondary" bare soil (Chapman 1940), so-named because they were previously vegetated. Marsh pans are permanent, nonvegetated depressions in the soil surface that retain standing water at low tide (Yapp and Johns 1917). Several authors have suggested that patches of secondary bare soil devegetated by tidal wrack may become marsh pans (Warming 1904, Harshberger 1916, Nichols 1920, McCaffrey 1976).

So far there has been no systematic study of the origin or long-term effects of wrack in any salt marsh. This report deals with wrack in a young marsh on Wallops Island, Virginia. The impact of wrack was studied over two years.

## METHODS

The salt marsh used in the Intensive Biometric Intertidal Survey (IBIS) project is part of Cow Gut Flat marsh, which is on northern Wallops Island, Virginia (Figure 1). It is a juvenile sloping foreshore marsh after Redfield (1972), dominated by tall (highest stalks 1.5 to 2 m) and medium (1 to 1.5 m) growth forms of *Spartina alterniflora*. Zonation resembles that of similar marshes in North Carolina (Davis and Gray 1966): monospecific stands of tall and medium growth forms of *S. alterniflora* in low marsh (below mean high water, MHW); medium growth form *S. alterniflora* intermixed with subdominates *Salicornia* spp., *Distichlis spicata*, and *Limonium* sp., in the transition zone from low to high marsh (from MHW to mean high water springs, MHWS); and *Spartina patens*, *D. spicata*, and some *S. alterniflora*, intermixed with saltbushes, *Iva frutescens* and *Baccharis halimifolia*, in high marsh (above MHWS). Mean tidal range along Cow Gut Flat is 0.8 m.

In April and May 1975, 203 hardwood stakes were set at 10 m by 10 m intervals within the marsh (Figure 2). Many parameters of the marked study site, including elevation, historical development, species distributions, population densities, productivity, and edaphic parameters, were studied during 1975 and 1976 (summary in Reidenbaugh 1978; see also Hoffman 1978; Crist, in preparation). Tidal data were calculated using estimates of the National Ocean Survey for Chincoteague Point, Virginia (Reidenbaugh 1978).

Color infrared (IR) aerial photos (Kodak film 2443) were taken of the study site at scales from 1:20,000 to 1:2,000 during seven National Aeronautics and Space Administration (NASA) overflights from 1974 to 1976. (Flight numbers are available in Reidenbaugh 1978.) Photos were enlarged to 1:1,333 on a reflecting projector and aligned by white reflectors on stakes, or (before stakes were set) aligned by conspicuous ground features. Boundaries of mapping units were traced on acetate and photoreduced (Figure 2). The species composition of mapping units was checked on the

IBIS contribution 2.

Manuscript received July 10, 1979; accepted February 27, 1980.

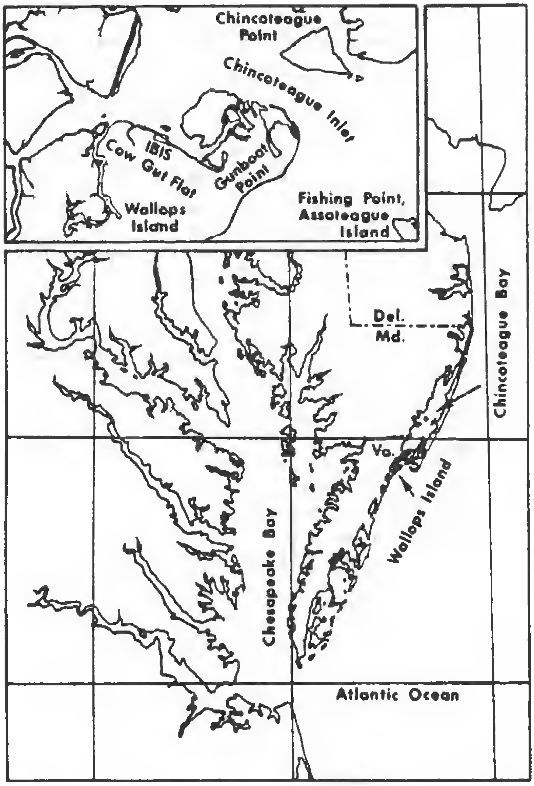


**Figure 1. Locality map for salt marsh IBIS, Cow Gut Flat, Wallops Island, Virginia, 37°54´N, 75°26´W.**

ground during three quadrat samplings of all stakes during 1975, and by standardized ground photos using black and white and natural color film. Eight mapping units were recognized for the purpose of this study:

1. An essentially monospecific stand of medium to high density *Spartina alterniflora,* with 190 to 550 overstory stalks per square meter, depending on mortality during the growing season (Reidenbaugh 1978). This zone consists of three areas recognizable in aerial IR photos:

   a. Tall *Spartina;* in low marsh areas with soft substrate. Highest frequently occurring stalks, 1 to 2 m. IR signature: textured pink to bright red in summer, textured dark green to blue-green in winter.

   b. Levee *Spartina;* in higher, quickly drained areas of firm, sandy substrate on a fossil sand bar and just below high marsh. Highest frequently occurring stalks, 0.5 to 1 m. IR signature: even green-red to red-tan in summer; even green to gray-green in winter.

   c. Middle marsh *Spartina;* in low, slowly drained areas with soft substrate. Highest frequently occurring stalks, 0.5 to 1.5 m. IR signature: mottled blue-pink to dark green-red in summer; mottled green to blue-green in winter.

2. Low density *S. alterniflora;* scattered in areas of levee and middle marsh *Spartina.* 70 to 170 stalks per square meter. Substrate firm to soft. Highest frequently occurring stalks, 0.5 to 1.5 m. IR signature: textured blue to blue-pink or blue-red in summer; textured blue in winter.

3. Saltbushes; areas dominated by *Iva frutescens* and *Baccharis halimifolia.* IR signature: individual bushes visible, pink to bright red in summer; green to gray-green in winter.

4. *Spartina* wrack. IR signature: textured blue-white to white or tan-white, all seasons.

5. *S. alterniflora* growing through *Spartina* wrack. IR signature: sparse, textured pink over *Spartina* wrack signature.

6. *Spartina* wrack mixed with saltbushes. IR signature: individual bushes visible; pink to bright red in summer, green to gray-green in winter; white wrack visible around bushes.

7. Bare marsh soil. Little or no rooted vegetation. IR signature: even light blue to dark blue.

8. A pan similar to bare marsh soil (7), but darker blue-black in IR photos, or with sun glint at low tides. Recognizable by its presence in imagery for over 10 years.

More specific details on the composition of the mapping units used herein are available in Reidenbaugh (1978).

All eight units are mapped in Figure 2. Although similar maps were prepared for all the relevant imagery (Reidenbaugh 1978), it was convenient here to further lump the vegetation categories as follows (Figure 3): categories 1 and 3 were lumped as "salt marsh"; low density *S. alterniflora* (category 2), bare soil (category 7), and pans (category 8) were not changed. Only a few of the maps prepared are illustrated here.

Additional observations of wrack were made *in situ* in 1978.

## RESULTS AND DISCUSSION

Mats of tidal wrack were first observed in early June 1974 (Figure 2). New mats were deposited during spring 1975, 1976, and 1978 (no data for 1977) (Figures 4 and 5). New wrack did not appear during any other time of the year. Apparently, wrack was formed by wave- and ice-scouring of the previous season's dead vegetation. Wrack entered the marsh well after scouring each year, presumably because it was ice bound and because tide levels in early spring are low (Marmer 1951). At Salt Marsh IBIS, average high tide levels may be 0.3 m lower in winter than in late summer (Reidenbaugh 1978). The wrack was composed almost entirely of detached leaves and leafless stalks of tall growth form *S. alterniflora* (Figure 5). The tall growth form can be recognized by the longitudinal distance between whorls of leaf scars (see Reidenbaugh 1978). Tall growth form *S. alterniflora* grows along the lowest, most seaward edge of the marsh, and is therefore much more susceptible to winter

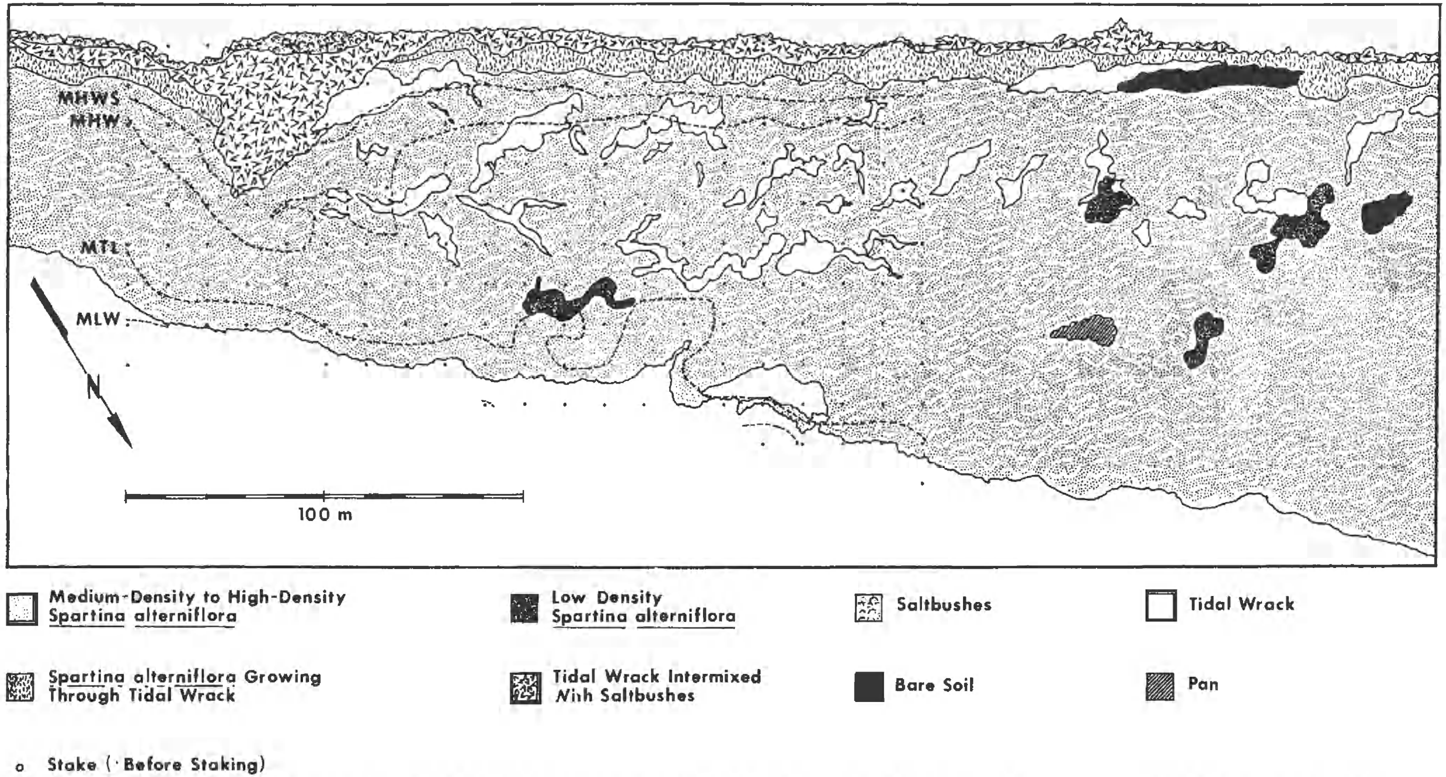


Figure 2. Map of cover types in the study area, June 4, 1974. Upland at top, Chincoteague Bay below. Dots represent locations of stakes set in place the following year; compare Figures 3 and 7. Dashed lines indicate tidal datum planes. Base map: NASA Mission W735, July 19, 1976; this map: NASA Mission W271, June 4, 1974.

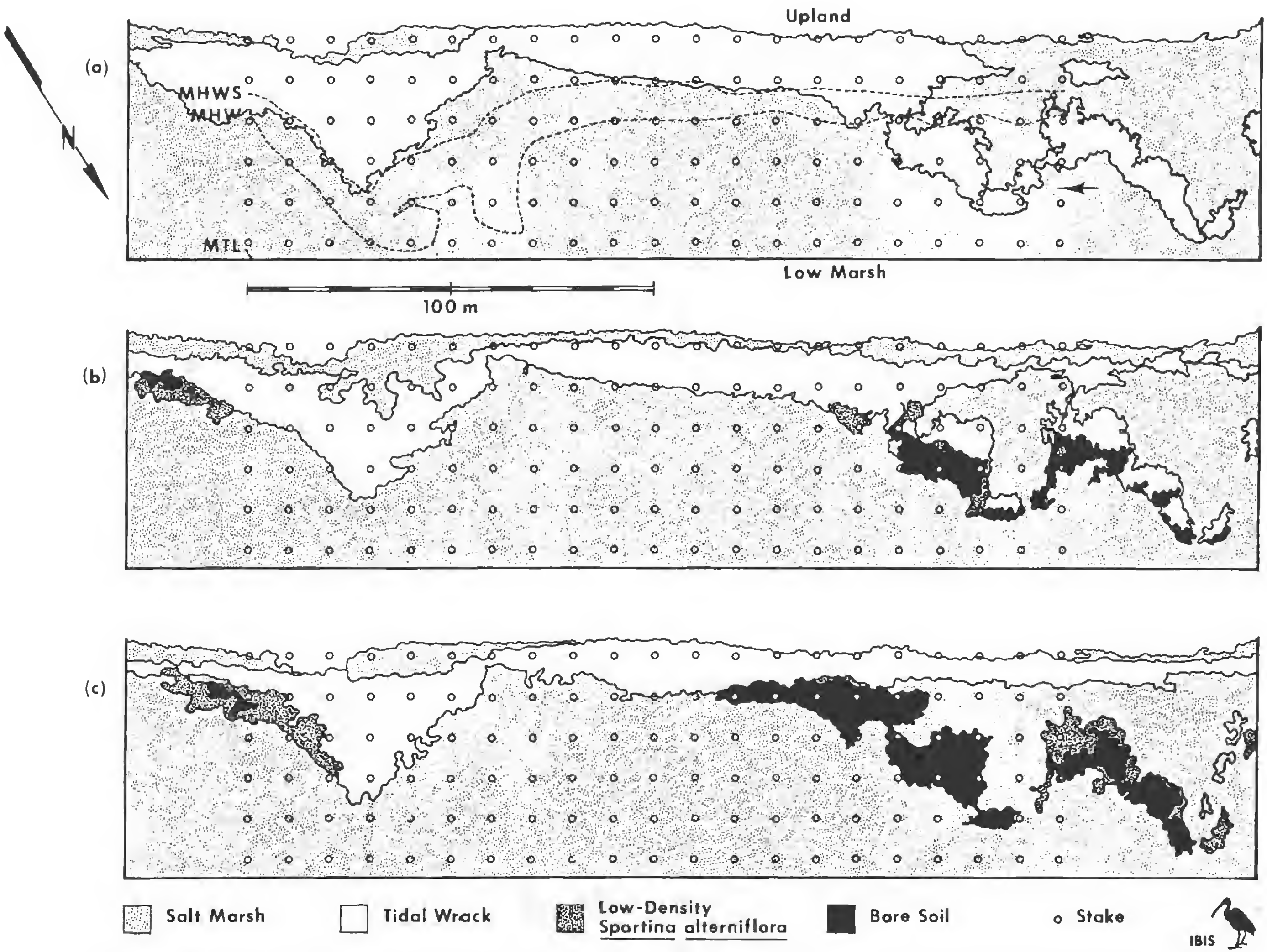


Figure 3. A single year's devegatation by tidal wrack in the upper part of salt marsh IBIS. Compare Figure 2. (a) NASA Mission W324, May 28, 1975; (b) NASA Mission W343, September 3, 1975; (c) NASA Mission W353, November 26, 1975. About 6 months between (a) and (c).

Figure 4. Medium growth form of *S. alterniflora* in salt marsh IBIS, May 20, 1975. The location and direction from which the photo was taken is indicated by the arrow at right in Figure 3(a).

Figure 5. Medium growth form of *S. alterniflora* in salt marsh IBIS, July 23, 1975—two months later than Figure 4. Mats of wrack cover the grass at left.

scouring than are the shorter growth forms. Tides are lowest in the winter when most scouring occurs, so lower elevations are more heavily and more frequently subjected to scouring by waves and ice.

Conspicuous mats of wrack were not seen until just after spring ice melts, during time of increasing tide heights. Most of the wrack seen in the IBIS marsh probably originated nearby; little wrack was ever seen floating offshore, despite near-daily observations during the spring of 1975 to 1977. It seems likely, therefore, that little long distance transport takes place.

Compared to adjacent areas, the IBIS study site received relatively large amounts of wrack. The study site is more directly exposed to waves and drifting ice from Chincoteague Bay than adjacent areas, which are protected by geographical features such as marsh islands or sand. No evidence was found to suggest that the stakes affected accumulation of wrack—there was about as much before staking as after (compare Figures 2 and 3).

Mats of wrack were rafted upward in the marsh by increasingly high tides; as the tides went out, mats were left behind. Mats stranded in low marsh, or in the transition zone from low to high marsh, were soon moved higher. Once mats made it to high marsh, they remained in place and gradually decomposed. Significant downward movement occurred only once (April 1976), but even then, only relatively small amounts were involved.

Upward movements of mats probably result from three effects. (1) Tide heights gradually increase from spring to fall. (2) Seasonal storm tides caused by northeasterly or southeasterly winds drive water through Chincoteague Inlet, increasing the water level. Storm winds slow ebb tides and blow wrack into the marsh. (3) Winds bend *Spartina* stalks toward the upland. This permits wrack to drift over them, but slows it when the wrack tends to drift back.

New wrack can be distinguished from old wrack, both in the field and in IR photos.

"New" wrack, wrack settled during the same growing season, forms thick mats often over 20 cm deep. It is composed of densely interwoven, long, hard stems and some dead leaves. New wrack generally is at lower elevations than old wrack, or often overlays it. In color IR, new wrack is very light, nearly white. When wet it is tinged with tan or blue. The texture is coarse, and the underlying substrate is completely obscured.

"Old" wrack, from the previous growing season, forms thinner mats, usually less than 20 cm deep. Mats are composed of short stem fragments, partly decomposed, and various amounts of finer detritus, increasing with age. Old wrack was seen only at higher elevations, often piled in the saltbush zone. Old wrack often contains more water than new wrack. In IR photos, old wrack has a smoother texture than new wrack, and is slightly darker. *S. alterniflora* may grow through old wrack, appearing pink and heavily textured. Where wrack is partly obscured by saltbushes, old and new wrack are hard to distinguish by IR photos, and only field observations will do.

*Spartina* wrack may kill large amounts of underlying vegetation under certain conditions (Figures 4, 5, 6 and 7). Mats stranded in low marsh for more than a few weeks in the spring caused complete devegetation. Wrack stranded later in the growing season caused only partial devegetation in low marsh. Presumably, taller *Spartina* plants survive better than sprouts. At higher elevations, in the transition zone from low to high marsh, mats usually caused only partial devegetation, even in spring. At high elevations, where wrack is stranded most of the year, eventually *S. alterniflora* will emerge through the wrack, but partial or complete diebacks sometimes occurred. Narrow patches of bare soil and low density *Spartina* resulted (Figures 6 and 7). This may account for the "barren zone" described by Guss (1972) from aerial photos in which wrack also was seen.

The movements and effects of wrack in the IBIS marsh are summarized in Figure 8.

Figure 6. Medium growth form of *S. alterniflora* in salt marsh IBIS, January 5, 1976–five months later than Figure 5. The wrack has killed back underlying vegetation, leaving secondary bare soil.

Amounts of marsh devegetation by tidal wrack varied greatly from year to year. In low marsh, and in the transition zone from low to high marsh, there were fourteen local diebacks in 1974, and eight in 1975. These devegetated areas totaled about 0.1 ha of marsh each year. In 1976, there were no diebacks below high marsh; extraordinarily high tides rafted wrack into high marsh in early spring before the *S. alterniflora* growing season, precluding diebacks at lower elevations.

Vegetation diebacks beneath tidal wrack did not form pans in the marsh, although significant short-term erosion occurred in devegetated areas. Patches of secondary bare soil eroded at an average rate of 5 mm $yr^{-1}$, over 3 years; patches of low density *S. alterniflora* eroded at 4 mm $yr^{-1}$ (Varricchio et al., in preparation). During the same time, surrounding marsh areas of medium to high density, medium growth form *S. alterniflora* accreted at 1 mm $yr^{-1}$ (Varricchio et al., in preparation). In some cases, patches of secondary bare soil persisted more than 2 years, but all eventually revegetated. In this juvenile marsh, organic content of sediments may be too low (2 to 4% by weight), and sand content too high (84 to 91% by weight) (Reidenbaugh 1978), to allow secondary pan formation by below ground organic decomposition and sediment compaction. The only pan in the Cow Gut Flat marsh formed as a primary pan when it was isolated in a relatively low area behind a sand bar by marsh colonization at both ends of the bar. In marshes where organic content is higher, decomposition combined with erosion may possibly lead to pan formation.

Vegetation diebacks were the major cause of low density *S. alterniflora* areas, and the sole cause of secondary bare soil areas in the marsh during this study. This temporary devegetation substantially reduced *S. alterniflora* productivity of the marsh. In medium to high density areas of medium growth form *S. alterniflora*, adjacent to devegetated areas, the net aerial productivity ranged from 580 to 1,020 g dry weight $m^{-2}$ $yr^{-1}$. In bare soil and low density *S. alterniflora* areas, productivity was reduced from 0 to 400 g $m^{-2}$ $y^{-1}$ (Reidenbaugh 1978). In 1976, 11% of the total *S. alterniflora* marsh area in the study site (15% of the medium growth form area), had been wholly or partly devegetated by tidal wrack; total *S. alterniflora* net area productivity of the site was reduced 8% (medium growth form *S. alterniflora* productivity was reduced 15%) compared to nonaffected marsh (calculated from Reidenbaugh 1978).

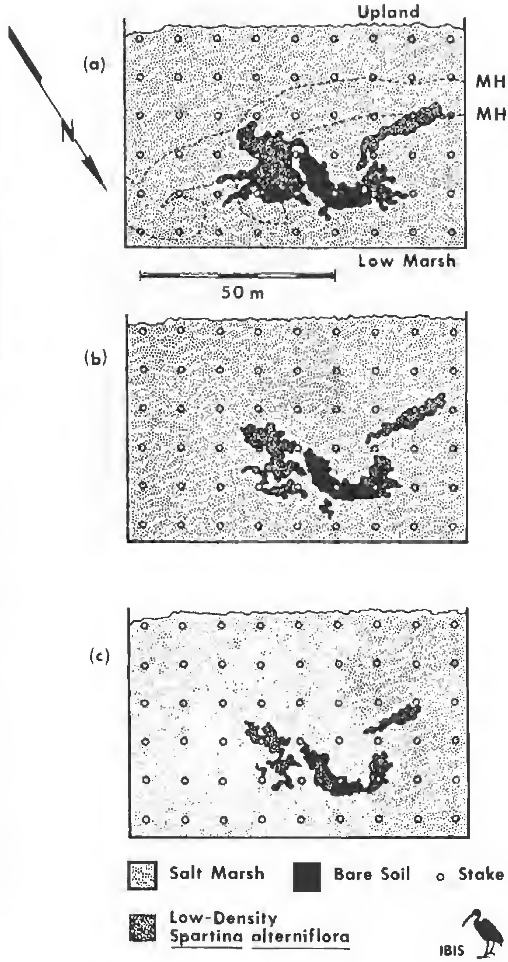


Figure 7. Revegetation of areas of marsh devegetated by wrack in 1974. (a) NASA Mission W324, May 28, 1975; (b) NASA Mission W353, November 26 1975; (c) NASA Mission W383, August 11, 1976. About 15 months between (a) and (c).

Wrack may be a major pathway of bulk detritus flux in some marshes. Much of the plant biomass produced in low marsh is transported upward in the marsh as wrack, and eventually decomposes in high marsh. Some of this biomass

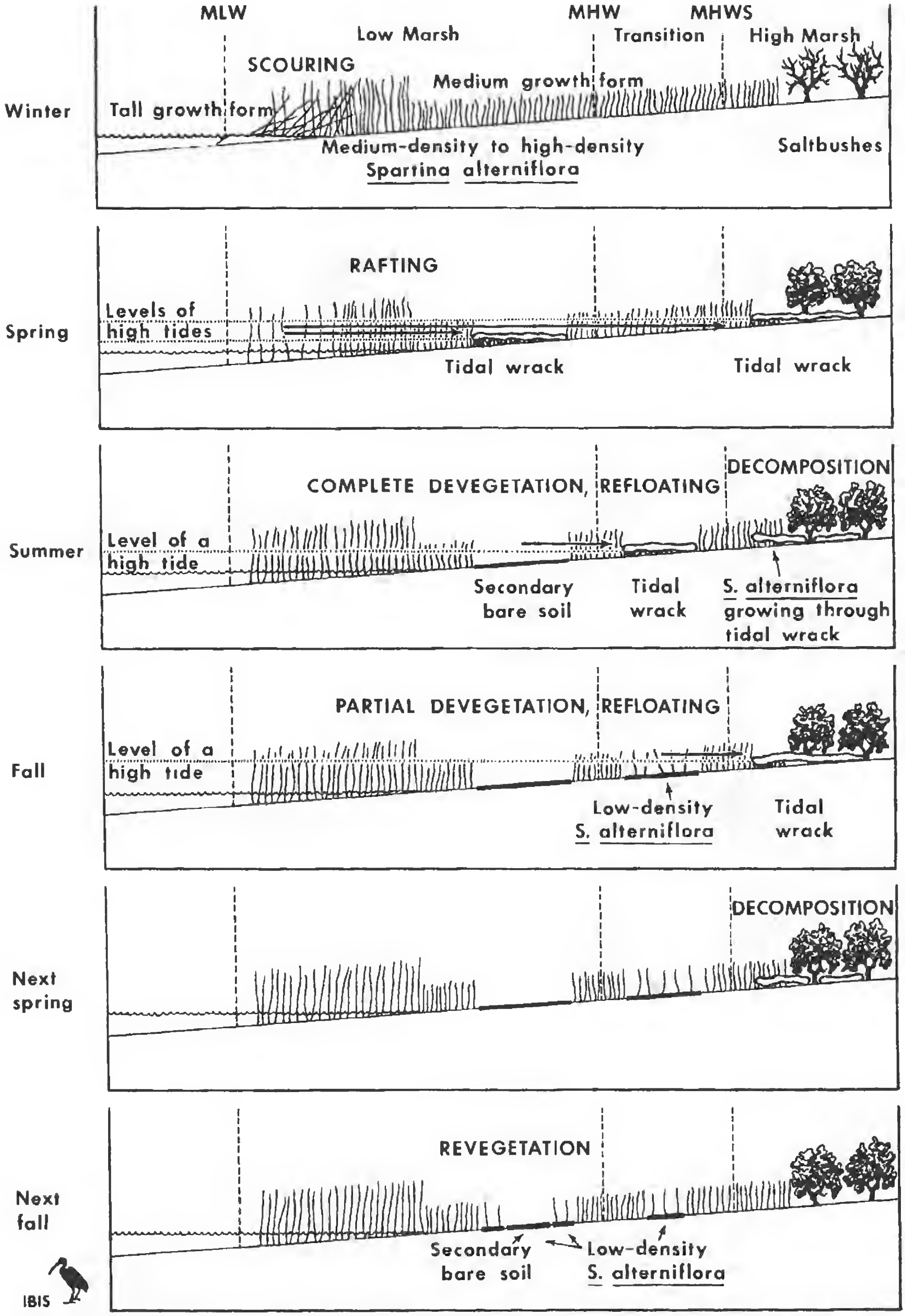


Figure 8. Diagram of the origin and effects of tidal wrack in salt marsh IBIS. Suggestions by M. A. Champ led to this artwork.

is incorporated into high marsh soils as organic material. High marsh at Cow Gut Flat was formerly an uncolonized beach ridge. Though organic content of the high marsh soils is only 3%, it is greater than in most lower marsh zones in this juvenile marsh (Reidenbaugh 1978). Most of the biomass is leached from wrack as finer detritus and probably enters the water column during tidal flooding. In high marsh, wrack detritus may contribute to sediment accretion. At Cow Gut Flat, short-term high marsh accretion is 2 mm $yr^{-1}$ (Varricchio et al., in preparation). In low marsh and in the transition zone from low to high marsh, devegetation caused by wrack results in sediment erosion, at 4 to 5 mm $yr^{-1}$ in this marsh (Varricchio et al., in preparation). Here, the organic content of sediments is very low compared to other marshes; erosion probably occurs from increased tidal and wind scouring in devegetated areas, and from decreased interference with the water column to cause settling of suspended particles.

## SUMMARY AND CONCLUSIONS

Mats of tidal wrack and areas devegetated by wrack are transitory features in salt marshes. They may be successfully monitored in sequential color IR aerial photos.

New mats of tidal wrack are formed by winter scouring of standing dead stalks of tall growth form *S. alterniflora* in lowest low marsh, and are rafted upward into the sloping foreshore salt marsh each spring. The mats settle over emergent vegetation from low to high marsh, depending on tide height. Mats stranded in high marsh decompose in place and living vegetation emerges through the wrack. Mats stranded in low marsh or in the transition zone from low to high marsh are refloated to high marsh by successively higher tides during summer or fall.

If mats cover areas of low marsh or the transition zone from low to high marsh during the growing season, underlying medium growth form *S. alterniflora* wholly or partly dies back, forming patches of secondary bare soil or low density *S. alterniflora*. Diebacks beneath tidal wrack are the major cause of devegetated areas within the Cow Gut Flat marsh. Severity of diebacks depends on marsh elevation, and time of year during the growing season of vegetation covered by wrack, with most serious diebacks occurring in low marsh, and in spring. Amounts of marsh devegetated varied greatly between years, depending on highest tide levels during early spring.

Secondary bare soil devegetated by wrack may persist 2 years or more. However, in this marsh, all devegetated areas eventually revegetated, and did not evolve into secondary pans. Sediment erosion occurred in devegetated areas, but it was suggested that organic content may be too low, and sand content may be too high, in the juvenile marsh sediment to allow pan formation by below-ground decomposition and compaction. Pans have formed only for geological reasons in this marsh.

Temporary devegetation caused by tidal wrack substantially reduced *S. alterniflora* productivity in the Cow Gut Flat marsh. As much as 11% of the *S. alterniflora* marsh area may be devegetated, and total *S. alterniflora* net aerial productivity may be reduced as much as 8%. Scouring and rafting of tidal wrack are enhanced by direct wave exposure of the marsh; because the Cow Gut Flat study site is directly exposed to waves from Chincoteague Inlet, measured impacts of tidal wrack are probably relatively very high.

## ACKNOWLEDGMENTS

This research is partly taken from a M.S. thesis in biology at The American University (T.G.R.). The research is part of Project IBIS (Intensive Biometric Intertidal Survey), a student-oriented research project in salt marsh ecology. We especially thank these IBIS members for making much of the research possible: R. Wyle Crist, Anna E. Hoffman, Douglas A. Hornbeck, Donna M. Krivach, Robert R. Reidenbaugh II, Richard S. Sigman, Daxel V. Tarner, and Karen Carroll Tarner. We also thank Drs. Richard A. Anderson and Michael A. Champ for technical help. This research was supported in part by the National Science Foundation and the Griffis Foundation. We are indebted to the staff of the Wallops Island Flight Center of NASA, who generously provided the IBIS study site and laboratory space on Wallops Island, the aerial photography, and the interpretive facilities. The Marine Science Consortium, Inc., provided logistical support, especially through Mr. Richard D. White and Mr. Robert Swift. The American University supplied indirect support.

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# Gulf Research Reports

Volume 6 | Issue 4

January 1980


Studies on *Amyloodinium ocellatum* (Dinoflagellata) in Mississippi Sound: Natural and Experimental Hosts


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DOI: 10.18785/grr.0604.08

*Gulf Research Reports*, Vol. 6, No. 4, 403–413, 1980.

# STUDIES ON *AMYLOODINIUM OCELLATUM* (DINOFLAGELLATA) IN MISSISSIPPI SOUND: NATURAL AND EXPERIMENTAL HOSTS[1]

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*ABSTRACT* Four species of parasitic dinoflagellates have been found to occur naturally on the gills and fins of Mississippi Sound fishes: *Amyloodinium ocellatum* (Brown 1931) Brown and Hovasse 1946, *Oodinium cyprinodontum* Lawler 1967, and two undescribed species. Sixteen of 43 species of fishes examined had natural gill infections of *A. ocellatum*. Seventy-one of 79 species of fishes exposed to *A. ocellatum* dinospores were susceptible, and succumbed, to the dinoflagellate. Eight did not die even though exposed to numerous dinospores. The most common signs in an infested fish were spasmodic gasping and uncoordinated movements. Trophonts of *A. ocellatum* were found on the gills, skin, fins, eyes, pseudobranchs, membranes of the branchial cavity and around the teeth; and in the lateral line pits, nasal passages, esophagus, and intestine of experimentally infected fishes. The dinoflagellate causes extensive mortalities of fishes held under closed-system mariculture conditions.

## INTRODUCTION

Parasitic dinoflagellates were first reported from vertebrates by Brown (1931), who described *Oodinium* (= *Amyloodinium*) *ocellatum* from marine aquarium fishes. Additional references to this species are those by Brown (1934), Nigrelli (1936, 1939, 1940), Brown and Hovasse (1946), Chatton (1952), Porter (1952), Dempster (1955, 1956, 1972), Laird (1956), Simkatis (1958), Højgaard (1962), Paccaud (1962), Chlupaty (1962), Buxton (1962), Graaf (1962), Valenti (1968), Kingsford (1975), Becker (1977), and Lawler (1977a, 1977b, 1979).

*Oodinium limneticum*, a species from freshwater fishes, was described by Jacobs (1946); additional references are those by Kozloff (1948, 1949), Patterson (1949), and Lewis (1963). Another freshwater species, *O. pillularis* Schäperclaus, 1954, has received considerable attention in Europe (Weiser 1949; Schäperclaus 1951; Hirschmann and Partsch 1953; Reichenbach-Klinke 1954, 1955, 1956, 1961; Schubert 1959; Geus, 1960a, 1960b, 1960c, 1960d; Reichenbach-Klinke and Elkan 1965; and Lucky 1970.

An estuarine species, *O. cyprinodontum*, was described from Virginia cyprinodontids by Lawler (1967). It has been reported by Dillon (1966), Lawler (1967, 1968a, 1968b), Lom and Lawler (1971, 1973), and Williams (1972). Of these species, only *O. pillularis* has not been reported from North America. Unidentified parasitic dinoflagellates from North American fishes have been reported by Overstreet (1968), Lom and Lawler (1971, 1973), and Paperna and Zwerner (1976). *Oodinium cyprinodontum* has been reported from the Gulf of Mexico (Williams 1972); Kingsford (1975) illustrated a trophont from a mangrove snapper (*Lutjanus griseus*) with an *A. ocellatum* infection, presumably from the eastern Gulf of Mexico.

*Amyloodinium ocellatum* (Brown 1931) causes extensive mortalities of fishes in confined areas (Brown 1931, 1934; Nigrelli 1936, 1939, 1940; Højgaard 1962; Lawler 1977a, 1977b), and has been reported from many species of marine teleosts (Brown 1934; Nigrelli 1936, 1940; Brown and Hovasse 1946; Dempster 1955, 1956; Chlupaty 1962; Graaf 1962; Paccaud 1962; Straughan 1970; Lawler 1979). *Oodinium cyprinodontum* Lawler 1967 has not yet been found to cause fish deaths in aquaria (Lawler, unpublished).

In October 1971, I started trying to control *A. ocellatum* on *Micropogonias undulatus* which were being held for experiments on lymphocystis (Cook 1972). Studies were initiated to ascertain the following: (1) identity of the species of parasitic dinoflagellates naturally present on fishes of Mississippi Sound; (2) the natural hosts of parasitic dinoflagellates in Mississippi waters; (3) those fishes susceptible to *A. ocellatum* in aquaria; and (4) the methods for controlling dinospores and trophonts of *A. ocellatum* in aquaria. The present report includes my findings thus far on the first three items. The results of efforts to control the parasites will be presented in a future report.

## MATERIALS AND METHODS

Fishes were collected mainly in Mississippi Sound, from Biloxi Bay to Horn Island, by means of trawls, traps, dip nets, and hook and line. Salinity was determined with a refractometer. Fishes were held alive in water from their place of capture and examined within a day. The fishes were bled by gutting them or cutting their tail to draw the blood away from the gills, thus facilitating examination of the excised gills under reflected light with a dissecting microscope. The gills of fishes collected were examined for natural infections in autoclaved seawater to avoid introduction of fortuitous dinoflagellates. Infected filaments were removed with irridectory scissors and the live trophonts were examined with a compound microscope for the presence of a stigma, stomopode, and other morphological characters.

[1]This study was conducted in part in cooperation with the U.S. Department of Commerce, NOAA, National Marine Fisheries Service, under PL 88–309, Project No. 2–262–R.

Manuscript received August 1, 1979; accepted October 10, 1979.

To ascertain the fishes susceptible to *A. ocellatum,* live individuals were placed in several 1- to 100-gallon aquaria with high concentrations of dinospores; the fishes were fed periodically. High levels of dinospores were ensured by periodically introducing susceptible fishes. When the introduced fishes died, they were either left in the tanks so the dinoflagellates could encyst and fall to the tank bottoms, or their excised gills were returned to the tanks. The date and time of introduction for each fish into experimental infection tanks were recorded so that an idea of how fast *A. ocellatum* killed each fish could be determined. However, since dinospore concentrations could not be adequately monitored in a tank, the intensity of attacks could only be estimated by the number of trophonts present per gill filament at the death of the fish. All introduced test fishes were watched closely and were examined at or near death for the presence of dinoflagellates. The date and time of each death were recorded. Trophont morphology and the presence of a stigma were confirmed for each infection.

Three quick ways to check for *A. ocellatum* without excising the gills and killing the host are to: (1) quickly lift the opercule of a fish and examine the gills under a dissecting microscope; (2) immerse and hold down a live fish in a dish of water and examine the eyes and fins; or (3) brush a live fish held in a dish of water and examine the bottom of the dish for dislodged trophonts.

All scientific names of fish hosts are according to Bailey et al. (1970) except *Micropogonias undulatus*, which has undergone a name change (Chao 1978). Measurements are given in microns.

## RESULTS AND DISCUSSION

### *Parasitic Dinoflagellates Recovered*

A list of hosts for four parasitic dinoflagellates is presented in Table 1.

*Species 1:* This species is presently considered to be *Amyloodinium ocellatum* (Brown 1931) Brown and Hovasse, 1946 because: (1) morphology and size of the trophont compare with that described by Brown (1934) and Brown and Hovasse (1946); (2) a red stigma is present; (3) a stomopode ("root-like process" of Brown and Hovasse, 1946; "flagellum" of Nigrelli, 1936) is present; and (4) the stigma persists throughout all stages (Brown and Hovasse 1946). Even though it can be keyed out to *A. ocellatum* using the key presented by Brown and Hovasse (1946), the majority of dinospores differed somewhat in shape and size from those described by Brown (1934), Nigrelli (1936), and Brown and Hovasse (1946). Some spores were more flattened anteriorly-posteriorly than others. Dinospore characteristics are: red stigma in hypocone; epicone smaller than hypocone; one flagellum in a very distinct girdle with an undulating beat, and the sulcal flagellum long with a more or less back and forth beat; body 11.6–15.4 long by 10.4–14.5 wide (N = 10), apparently after the last division. Dinospores free-swimming for at least 15 days. Pyriform trophonts up to 350 long, but most usually 150 or less. Trophonts nonpigmented, containing starch granules, vacuoles, and a large nucleus, and possessing a red stigma, stomopode, and attachment rhizoids. Cysts held in seawater were allowed to divide and the following observations were made: (1) all the cells do not divide at once, (2) the stigma is retained throughout division stages as noted by Nigrelli (1936), and (3) cells in division stages are in columns as noted by Nigrelli (1936).

*Species 2:* Spherical to elongate with greenish pigment and reddish granules; holdfast and stomopode not observed. This is possibly a free-living dinoflagellate which adheres to the mucus of fish skin and gills.

*Species 3:* Larger and more robust than *A. ocellatum;* no pigment or stigma; stomopode present; broad holdfast disc with numerous rhizoids; distal, large nucleus. This is possibly the same species as reported by Overstreet (1968).

*Species 4:* The fourth species, *Oodinium cyprinodontum* Lawler 1967, has already been reported from the Gulf of Mexico by Williams (1972), from gills of both *Fundulus similis* (Baird and Girard) and *Cyprinodon variegatus* Lacépède collected near Pensacola, Florida, and Mobile Bay, Alabama, respectively. I recovered *O. cyprinodontum* from the same two hosts from various localities (Deer and Horn islands, Davis Bayou) in Mississippi Sound. It was also recovered from another cyprinodontid, *Adinia xenica* (Jordan and Gilbert), a new host record, from Horn Island; of five fish examined, one individual was observed.

### *Natural Hosts of Amyloodinium ocellatum*

Of 99 fishes examined, representing 43 species from 28 families, 16 species of 13 families were found to be infected naturally with *A. ocellatum* on the gills (Table 1). This represents more natural hosts than previously reported. Natural infections generally are very light in Mississippi waters, and apparently cause no deaths. The natural prevalence and intensity of *A. ocellatum* on *Micropogonias undulatus* (Linnaeus) in Mississippi waters will be discussed by Dr. Robin M. Overstreet (in preparation). The natural intensity on fishes I examined generally was low; however, one specimen of *Cynoscion nebulosus* (Cuvier) had 115 *A. ocellatum* on its gills. This number still is far short of the several thousand necessary to kill the host. Three of the hosts from the present study previously have been reported to be susceptible to *A. ocellatum* (Table 1); the rest were reported recently as new host records by Lawler (1979). Nigrelli (1936) assumed that *Chilomycterus schoepfi* (Walbaum) was a natural host which, when introduced into the New York Aquarium closed-circulation tanks, spread the parasite to other fishes. Brown (1934) found that *Holocentrus ascensionis* (Osbeck), *Teuthis bahianus* (= *Acanthurus bahianus* Castelnau), and *Glyphisodon saxatilis* (= *Abudefduf saxatilis* [Linnaeus] ?) had very slight infections of *A. ocellatum* when they arrived dead in a consignment of fish from Bermuda. Dempster (1955) found *A. ocellatum* on both the gills and body of *Amphyprion*

**TABLE 1.**

**Mississippi Sound fishes examined for the natural occurrence of parasitic dinoflagellates.***

| Species | mm Total Length (TL)[1] | Dinoflagellate species present | Number infected per number examined | Estimated number of dinoflagellates per infected host (gills) |
|---|---|---|---|---|
| **Acipenseridae** | | | | |
| *Acipenser oxyrhynchus desotoi* Vladykov | 1,065 SL (standard length) | – | 0/1 | – |
| **Lepisosteidae** | | | | |
| *Lepisosteus osseus* (Linnaeus) | 1,029 | – | 0/1 | – |
| **Elopidae** | | | | |
| *Elops saurus* Linnaeus | 267 | – | 0/1 | – |
| **Ophichthidae** | | | | |
| *Ophichthus gomesi* (Castelnau) | 273, 458, 508 | 1? | 1/3 | 1 |
| **Clupeidae** | | | | |
| *Brevoortia patronus* Goode | 232 | – | 0/1 | – |
| *Dorosoma petenense* (Günther) | 109 | – | 0/1 | – |
| **Synodontidae** | | | | |
| *Synodus foetens* (Linnaeus) | 206 | 3? | 1/2 (2/2) | 11 |
| | 229 | 1? | 1/2 | few |
| **Ariidae** | | | | |
| *Bagre marinus* (Mitchill) | 153, 157, 163 | 2? | 1/3 | several |
| **Batrachoididae** | | | | |
| *Porichthys porosissimus* (Valenciennes) | 163 | – | 0/1 | – |
| **Gadidae** | | | | |
| *Urophycis floridanus* (Bean and Dresel) | 61, 95, 106, 124, 203, 207 | – | 0/6 | – |
| **Cyprinodontidae** | | | | |
| *Adinia xenica* (Jordan and Gilbert) | 29, 29, 30, 30, 39 | 4 | 1/5 | 1 |
| *Cyprinodon variegatus* Lacépède | 41, 43 | 3 | 1/2 | 2 |
| | 37 | 4 | 2/3 | 25 |
| | 47 | 1? | 2/3 | 200 |
| | | 4 | | 14 |
| | 57 | 1? | | 150–200 |
| *Fundulus similis* (Baird and Girard) | ?, 39, 82 | 4 | 1/3 | 5 |
| **Poeciliidae** | | | | |
| *Poecilia latipinna* (Lesueur) | 37 | – | 0/1 | – |
| **Atherinidae** | | | | |
| *Menidia beryllina* (Cope) | 79 | – | 0/1 | – |
| **Serranidae** | | | | |
| *Centropristis ocyurus* (Jordan and Evermann) | 110 | – | 0/1 | – |
| *Centropristis philadelphica* (Linnaeus) | 115, 119 | – | 0/2 | – |
| **Carangidae** | | | | |
| *Selene vomer* (Linnaeus) | 113 | – | 0/1 | – |
| *Vomer setapinnis* (Mitchill) | 123 | – | 0/1 | – |
| **Lutjanidae** | | | | |
| [2,7] *Lutjanus griseus* (Linnaeus) | 72, 104 | 3? | 1/2 | 1 |
| [2] *Lutjanus analis* (Cuvier) | 150 | 1? | 1/1 | 2–3 |
| **Gerreidae** | | | | |
| *Eucinostomus argenteus* Baird and Girard | 79, 89 | 1? | 1/2 | 20–30 |
| **Sparidae** | | | | |
| *Archosargus probatocephalus* (Walbaum) | 305, 337 | 1 | 1/2 | 30–50 |
| *Lagodon rhomboides* (Linnaeus) | 106, 104 | 1 | 1/2 | less than one/filament |
| **Sciaenidae** | | | | |
| *Bairdiella chrysura* (Lacépède) | 50, 65 | – | 0/2 | |

TABLE 1 – Continued

| Species | mm Total Length (TL)[1] | Dinoflagellate species present | Number infected per number examined | Estimated number of dinoflagellates per infected host (gills) |
|---|---|---|---|---|
| *Cynoscion arenarius* Ginsburg | 100, 302 | – | 0/2 | – |
| *Cynoscion nebulosus* (Cuvier) | 170, 187, 222, 223, 230, 305 | 1 | 3/6 | 1–115 |
| [3]*Leiostomus xanthurus* Lacépède | 116, 129, 138, 233, 238 | – | 0/5 | – |
| *Menticirrhus americanus* (Linnaeus) | 167, 195, 211, 225 | 1 | 3/4 | 1–5 |
| *Micropogonias undulatus* (Linnaeus) | 310 | 1 | 1/1 | 50–100 |
| *Sciaenops ocellata* (Linnaeus) | 296, 407 | – | 0/2 | – |
| Mugilidae | | | | |
| [4]*Mugil cephalus* Linnaeus | 115, 239 | 1? | 1/2 | 1 |
| Blenniidae | | | | |
| *Hypsoblennius ionthas* (Jordan and Gilbert) | 47 | 1? | 1/1 | 1 |
| Gobiidae | | | | |
| *Gobionellus hastatus* Girard | 160 | – | 0/1 | – |
| *Gobiosoma bosci* (Lacépède) | 21, 28, 31 | 1 | 2/3 | 1 |
| Microdesmidae | | | | |
| *Microdesmus longipinnis* (Weymouth) | 129, 141, 150, 154, 202 | – | 0/5 | – |
| Trichiuridae | | | | |
| *Trichiurus lepturus* Linnaeus | 296 | – | 0/1 | – |
| Stromateidae | | | | |
| *Peprilus alepidotus* (Linnaeus) | 153 | – | 0/1 | – |
| *Peprilus burti* Fowler | 25, 73, 76, 83, 84, 86, 91 | – | 0/7 | – |
| Triglidae | | | | |
| *Prionotus rubio* Jordan | 55, 85 | 1 | 1/2 | 1 |
| Balistidae | | | | |
| *Monacanthus hispidus* (Linnaeus) | 65 | – | 0/1 | – |
| Ostraciidae | | | | |
| *Lactophrys quadricornis* (Linnaeus) | 88 | 1? | 1/1 | 2 |
| Diodontidae | | | | |
| [2,3,5,6]*Chilomycterus schoepfi* (Walbaum) | 219, 229, 257 | 1? | 1/3 | 9 |

*Parasitic dinoflagellate species recovered (see text):
Species 1 – *Amyloodinium ocellatum* (Brown, 1931).
Species 2 – Unidentified green-pigmented form with red granules (contaminate?).
Species 3 – Unidentified form with flagellum but no stigma.
Species 4 – *Oodinium cyprinodontum* Lawler, 1967.
[1]The total length of each infected fish is underlined.
Reported as a host for *Amyloodinium ocellatum* (Brown, 1931) by:
[2]Nigrelli (1940)
[3]Nigrelli (1936)
[4]Brown (1934)
[5]Brown and Hovasse (1946)
[6]Simkatis (1958)
[7]Kingsford (1975)

*percula* (Lacépède) that had been collected near Singapore. Simkatis (1958) found *Oodinium* (= *A. ocellatum*?) to infect *Chilomycterus schoepfi* and *Sphoeroides maculatus* (Bloch and Schneider) naturally. Porter (1952) thought that *A. ocellatum* was introduced into aquaria by newly arrived *Amphiprion ocellatum* (= *Amphyprion ocellaris* Cuvier).

*Experimental Hosts of Amyloodinium ocellatum*

Mississippi Sound hosts that are susceptible and succumb to *A. ocellatum* in aquaria are listed in Table 2. To date, 71 species of 39 families have been confirmed to die of *A. ocellatum* in aquaria. Seven had been reported previously as susceptible hosts (Table 2), the rest recently were reported

TABLE 2.

Mississippi Sound fishes experimentally infected by and succumbing to *Amyloodinium ocellatum*.

| Host | mm Total Length (TL) (range) | Number Infected |
|---|---|---|
| Dasyatidae | | |
| **Dasyatis sabina* (Lesueur) | 640–740 | 2 |
| Ophichthidae | | |
| **Myrophis punctatus* Lütken | 70–168 | 4 |
| **Ophichthus gomesi* (Castelnau) | 432–564 | 2 |
| Clupeidae | | |
| **Harengula jaguana* Poey | 56 | 1 |
| Engraulidae | | |
| **Anchoa mitchilli* (Valenciennes) | 29– 40 | 5 |
| Synodontidae | | |
| **Synodus foetens* (Linnaeus) | 37–216 | 2 |
| Ariidae | | |
| **Arius felis* (Linnaeus) | 104–228 | 5 |
| **Bagre marinus* (Mitchill) | 135 | 1 |
| Batrachoididae | | |
| **Opsanus beta* (Goode and Bean) | 25–163 | 6 |
| **Porichthys porosissimus* (Valenciennes) | 110–127 | 2 |
| Gobiesocidae | | |
| **Gobiesox strumosus* Cope | 57 | 1 |
| Gadidae | | |
| **Urophycis floridanus* (Bean and Dresel) | 184–197 | 3 |
| Exocoetidae | | |
| *flyingfish (unidentified) | 18– 33 | 4 |
| Cyprinodontidae | | |
| **Fundulus jenkinsi* (Evermann) | 20– 30 | several |
| Poeciliidae | | |
| **Gambusia affinis* (Baird and Girard) | 20– 30 | several |
| Syngnathidae | | |
| **Hippocampus erectus* Perry | 47– 50 | 2 |
| **Syngnathus louisianae* Günther | 128–232 | 6 |
| Percichthyidae | | |
| [1,2]*Morone saxatilis* (Walbaum) | 88–102 | 3 |
| Serranidae | | |
| **Centropristis philadelphica* (Linnaeus) | 97 | 1 |
| **Epinephelus niveatus* (Valenciennes) | 164 | 1 |
| **Serraniculus pumilio* Ginsburg | 61 | 1 |
| **Serranus subligarius* (Cope) | 120 | 1 |
| Grammistidae | | |
| **Rypticus maculatus* Holbrook | 205 | 1 |
| Centrarchidae | | |
| **Lepomis macrochirus* Rafinesque | 125 | 1 |
| Carangidae | | |
| [1]*Caranx hippos* (Linnaeus) | 32– 58 | 2 |
| **Caranx latus* Agassiz | 118 | 1 |
| **Chloroscombrus chrysurus* (Linnaeus) | 50– 55 | 3 |
| **Oligoplites saurus* (Bloch and Schneider) | 20–110 | 7 |
| **Trachinotus carolinus* (Linnaeus) | 60 | 1 |
| Lutjanidae | | |
| **Lutjanus campechanus* (Poey) | 83 | 1 |
| [2,6]*Lutjanus griseus* (Linnaeus) | 29–135 | 7 |
| Lobotidae | | |
| **Lobotes surinamensis* (Bloch) | 21– 55 | 6 |
| Gerreidae | | |
| **Eucinostomus argenteus* Baird and Girard | 36– 56 | 3 |
| Pomadasyidae | | |
| **Orthopristis chrysoptera* (Linneaus) | 187–223 | 2 |
| Sparidae | | |
| **Archosargus probatocephalus* (Walbaum) | 89–151 | 7 |

TABLE 2 – Continued

| Host | mm Total Length (TL) (range) | Number Infected |
|---|---|---|
| **Lagodon rhomboides* (Linnaeus) | 98–137 | 12 |
| **Sciaenidae** | | |
| **Bairdiella chrysura* (Lacépède) | 65–185 | 14 |
| **Cynoscion arenarius* Ginsburg | 71–277 | 6 |
| **Cynoscion nebulosus* (Cuvier) | 160 | 1 |
| **Equetus acuminatus* (Bloch and Schneider) | 70 | 2 |
| **Larimus fasciatus* Holbrook | 35– 80 | 2 |
| [1]*Leiostomus xanthurus* Lacépède | 104–223 | 11 |
| **Menticirrhus americanus* (Linnaeus) | 110 | 1 |
| **Micropogonias undulatus* (Linnaeus) | 169–196 | 3 |
| **Sciaenops ocellata* (Linnaeus) | ?–190 | 2 |
| **Ephippidae** | | |
| [1]*Chaetodipterus faber* (Broussonet) | 92 | 1 |
| **Mugilidae** | | |
| [3]*Mugil cephalus* Linnaeus | 88–110 | 5 |
| **Blenniidae** | | |
| **Chasmodes bosquianus* (Lacépède) | 15– 69 | 12 |
| **Hypsoblennius hentzi* (Lesueur) | 40– 57 | 2 |
| **Hypsoblennius ionthas* (Jordan and Gilbert) | ?– 86 | 10 |
| **Eleotridae** | | |
| **Eleotris pisonis* (Gmelin) | 94–114 | 3 |
| **Gobiidae** | | |
| **Bathygobius soporator* (Valenciennes) | 85 | 1 |
| **Gobioides broussonneti* Lacépède | 413 | 1 |
| **Gobiosoma bosci* (Lacépède) | 30– 56 | 8 |
| **Gobiosoma robustum* Ginsburg | 46 | 1 |
| **Microgobius gulosus* (Girard) | 32– 53 | 9 |
| **Microdesmidae** | | |
| **Microdesmus longipinnis* (Weymouth) | ?–135 | 4 |
| **Scorpaenidae** | | |
| **Scorpaena brasiliensis* Cuvier | 76 | 1 |
| **Triglidae** | | |
| **Prionotus roseus* Jordan and Evermann | 223 | 1 |
| **Prionotus tribulus* Cuvier | 102 | 1 |
| **Bothidae** | | |
| **Citharichthys spilopterus* Günther | 84– 92 | 3 |
| **Etropus crossotus* Jordan and Gilbert | 95–118 | 3 |
| **Paralichthys lethostigma* Jordan and Gilbert | 148–286 | 4 |
| **Soleidae** | | |
| **Achirus lineatus* (Linnaeus) | 34– 41 | 4 |
| **Trinectes maculatus* (Bloch and Schneider) | 56–109 | 13 |
| **Cynoglossidae** | | |
| **Symphurus plagiusa* (Linnaeus) | 39–124 | 11 |
| **Balistidae** | | |
| **Aluterus schoepfi* (Walbaum) | 46 | 1 |
| **Monacanthus hispidus* (Linnaeus) | 76– 79 | 2 |
| **Ostraciidae** | | |
| **Lactophrys quadricornis* (Linnaeus) | 60– 97 | 2 |
| **Tetraodontidae** | | |
| **Sphoeroides parvus* Shipp and Yerger | 50– 74 | 7 |
| **Diodontidae** | | |
| [1,2,4,5]*Chilomycterus schoepfi* (Walbaum) | 126–143 | 2 |

Reported as a host by:
*Lawler (1979)
[1]Nigrelli (1936)
[2]Nigrelli (1940)
[3]Brown (1934)
[4]Brown and Hovasse (1946)
[5]Simkatis (1958)
[6]Kingsford (1975)

as new hosts by Lawler (1979). There is no way of ascertaining if these susceptible fishes had light infections prior to their introduction into tanks containing dinospores. Fish deaths were noted as soon as 12 hours after introduction into tanks with high dinospore concentrations.

The numbers of infected fishes listed in Table 2 represent those hosts confirmed to have died from *A. ocellatum* after examination of fresh material with a compound microscope. Many more individuals of these fishes died from *A. ocellatum* in maintaining dinospore concentrations in tanks, in experimental host studies, and in treatment experiments. Because some fish died before they could be critically examined, only those confirmed to have died from *A. ocellatum* are enumerated in Table 2. Susceptible and locally abundant fishes such as *Arius felis, Oligoplites saurus, Lutjanus griseus, Archosargus probatocephalus, Lagodon rhomboides, Bairdiella chrysura, Leiostomus xanthurus, Micropogonias undulatus, Chaetodipterus faber, Hypsoblennius ionthas, Gobiosoma bosci, Achirus lineatus,* and *Trinectes maculatus* were employed in maintaining high dinospore concentrations. Their numerous deaths were not recorded.

Other susceptible hosts were reported by the following: Brown (1931, 1934); Schäperclaus (1935; as *Branchiophilus maris,* 1954); Nigrelli (1936, 1940); Brown and Hovasse (1946); Porter (1952); Dempster (1955, 1956); Laird (1956); Simkatis (1958); Amlacher (1961); Graaf (1962); Højgaard (1962); Paccaud (1962); Valenti (1968); Kingsford (1975); and Lawler (1979).

Ever since Brown (1934, p. 583) said that "provided conditions in the tanks are suitable it appears to attack all fish indiscriminately," most subsequent authors have stated that *A. ocellatum* appears "to be non-specific in host selection" (Sindermann 1970). This study, however, indicates that some Mississippi Sound fishes may not be susceptible to *A. ocellatum,* and others may become less susceptible with increasing size. Although definite proof has not yet been obtained, a few specimens of each of nine species of fishes were not found to die of *A. ocellatum* when exposed to dinospores (Table 3). One *Anguilla rostrata* stayed in an infection-tank from November 24, 1971 to June 21, 1972, but did not die from *A. ocellatum,* while several hundred other fishes died in the same tank in as little as 2 days. One *Fundulus grandis* lived in a tank with dinospores from November 24, 1971 to October 18, 1972; another specimen lived in a different infection tank from February 20 to October 24, 1972. Neither specimen died, although many other fishes introduced into the same tanks succumbed to the dinoflagellate. One *Menidia beryllina* (examined alive) had no *A. ocellatum* on its gills, but in the same tank, two stingrays *Dasyatis sabina* (Lesueur), exhibited massive (200 to 500 trophonts per gill filament) infections after the same 6-day exposure. The stingray represents the first record of an elasmobranch being susceptible to *A. ocellatum.* Also, *Opsanus beta* (Goode and Bean) appears to have some resistance to *A. ocellatum.* Although deaths of *O. beta* can result from exposure to *A. ocellatum* (Table 2), several specimens were never found to harbor the dinoflagellates on their gills when they died from other causes (Table 3). Four specimens of *O. beta* survived until June 25-27, 1972, without any evidence of *A. ocellatum* on their gills, even though 15 *Arius felis* and 8 *Trinectes maculatus* died from *A. ocellatum* in the same tank on May 20. Brown (1934) also noted that some species appear more susceptible to this parasite than others.

**TABLE 3.**

**Mississippi Sound fishes exposed to *Amyloodinium ocellatum* but not succumbing.**

| Species | mm TL (range) | Number exposed and examined |
|---|---|---|
| **Anguillidae** | | |
| *Anguilla rostrata* (Lesueur) | ?–570 | 4 |
| **Batrachoididae** | | |
| *Opsanus beta* (Goode and Bean) | ?–180 | 5 |
| **Cyprinodontidae** | | |
| *Cyprinodon variegatus* Lacépède | 30– 50 | several |
| *Fundulus grandis* Baird and Girard | 89–118 | 3 |
| *Fundulus grandis* Baird and Girard | – | 40 |
| *Fundulus similis* (Baird and Girard) | 62 | 1 |
| **Poeciliidae** | | |
| *Poecilia latipinna* (Lesueur) | 35– 54 | 7 |
| **Atherinidae** | | |
| *Menidia beryllina* (Cope) | 60– 79 | 7 |
| **Eleotridae** | | |
| *Dormitator maculatus* (Bloch) | 82 | 1 |
| *Dormitator maculatus* (Bloch) | – | 25 |
| **Gobiidae** | | |
| *Gobionellus hastatus* Girard | 138 | 1 |

Twenty lab-reared *Fundulus grandis* Baird and Girard (hatched March 26, 1978) were placed into each of two 5-gallon aquaria (salinity = 15 ppt) on July 10, 1978, and exposed to dinospores. *Amyloodinium ocellatum* cysts were added to the tanks 10 times between July 10 and October 3, 1978. None of the 40 fish so exposed died from *A. ocellatum.*

On October 12, 1977, 25 wild-caught sleepers, *Dormitator maculatus* (Bloch), were placed into a 75-gallon fiberglass tank (salinity = 17 ppt) where high dinospore concentrations had been maintained almost continuously since 1971. On July 26, 1979, eight of the sleepers were still alive; none of those that died were found to carry *A. ocellatum.* During this time period, approximately 310 fish of 15 species died of *A. ocellatum* in the same tank. Two of the sleepers were sacrificed during the study; no *A. ocellatum* were found on the gills of either one.

As noted above, when several species of fish are placed in an infection tank, some species will be affected and others will not. Conversely, if the species not affected is placed alone with dinospores, it may become affected. Also,

Nigrelli (1936) found that *Fundulus heteroclitus* (Linnaeus), when exposed to dinospores in a 2-gallon container, had infections of *A. ocellatum* on the second day; however, none were ever found infected in the New York Aquarium although they were in the presence of infected fishes.

Most of the host fish not affected either produce large amounts of mucus or can tolerate low oxygen levels. Possibly, heavy mucus production prevents attachment or the mucus of some species may contain a repellant.

The number of trophonts per gill filament necessary to kill a host varies with species and size of host. It also varies with size of the trophonts. Some examples are listed in Table 4.

All susceptible hosts reported prior to this study have been teleosts. Two *Dasyatis sabina* were placed in a tank with a high concentration of dinospores. Six days later they were still alive but badly stressed, being sluggish, and exhibiting an irregular spiracle beat (Table 5). Both were examined while still alive and were found to have a massive infection of 200 to 500 small to medium trophonts per gill filament; trophonts also were found in the olfactory organs. More extensive studies need to be made to ascertain all the species of fish that *A. ocellatum* will attack.

Dinospores did not attach to the skin of *Hyla cinerea cinerea* (Schneider) (= green tree frog) held partially submerged in water (salinity = 18 ppt) in a covered dish for 2 days with the free-swimming dinospores present throughout this period. This is significant because dinospores were observed swimming to the frog, bouncing around on the frog's skin, and then swimming off. I also found that a freshwater fish, *Lepomis macrochirus* Rafinesque, held in water with a salinity of 4 ppt, was susceptible to *A. ocellatum*. Trophonts occurred on the skin and gills, 46 on the first left gill arch alone indicating this was not a chance infection.

The signs of severely distressed fish, when they have been heavily infected by *A. ocellatum*, are listed by Brown (1934), Brown and Hovasse (1946), Dempster (1955, 1956), Straughan (1965, 1970), Valenti (1968), Lawler (1977a, 1977b), and others. These are: (1) having little or no interest in food, (2) rapidly gasping for air, (3) congregating near the surface, (4) scratching against objects in the tank, and (5) being sluggish unless prodded or chased by another fish. Brown (1934) was the first to note that different species may act differently when infected. She noted that clown fish either "rose to the top of the tank fluttering aimlessly, or lay at the bottom panting and incapable of co-ordinated movement" (Brown 1934, p. 603), whereas "*Julis pavo*, normally a bottom-living fish, frequently came to the top of the tanks gasping and often showed a curvature of the body," and other species became very sluggish. I have observed all of the above signs, which could also indicate one or more disorders other than infection by *A. ocellatum*. In addition, I note that any abnormal behavior of the fish may indicate an infection by *A. ocellatum*, the most common signs being spasmodic gasping, moving in an uncoordinated fashion, and squirting water in an effort to backflush gills (Table 5).

**TABLE 4.**

**A few examples of numbers of *Amyloodinium ocellatum* per gill filament and hours until death for various size fishes. Sizes of dinoflagellates were not measured.**

| Species | mm TL | Hours to death | Number of dinoflagellates per filament |
|---|---|---|---|
| *Arius felis* | 131 | 91 | 10– 40 |
| *Bagre marinus* | 135 | 53 | 10– 40 |
| *Bairdiella chrysura* | 168, 175, 185 | 38 | 20– 30 |
| *Bairdiella chrysura* | 166 | 31 | 50+ |
| *Caranx latus* | 118 | 21 | 100+ |
| *Chaetodipterus faber* | 92 | 30 | 40– 50 |
| *Chasmodes bosquianus* | 62 | 24 | 5– 20+ |
| *Cynoscion nebulosus* | 160 | 42 | 20– 50 |
| *Dasyatis sabina* | 640, 740 | 144* | 200–500+ |
| *Etropus crossotus* | 112 | 40 | 100+ |
| *Lagodon rhomboides* | 105, 131 | 161 | 50–100 |
| *Leiostomus xanthurus* | 120 | 39 | 20– 50 |
| *Leiostomus xanthurus* | 210 | 41 | 100–200 |
| *Lutjanus griseus* | 130 | 48 | 20– 30 |
| *Mugil cephalus* | 99 | 20 | 40– 50 |
| *Mugil cephalus* | 101, 101, 110 | 47 | 20– 50+ |
| *Orthropristis chrysoptera* | 223 | 39 | 300 |
| *Paralichthys lethostigma* | 148 | 52 | 20– 50 |
| *Paralichthys lethostigma* | 250 | 71 | 50–100 |
| *Sphoeroides parvus* | 50 | 28 | 75–100 |
| *Sphoeroides parvus* | 65 | 16 | 100–200+ |
| *Symphurus plagiusa* | 97 | 65 | 20– 30 |
| *Trinectes maculatus* | 56, 58, 65, 69 | 46 | 10– 40 |

*Moribund.

*Amyloodinium ocellatum* is reported to be primarily a gill parasite of marine fishes (Brown 1934, Brown and Hovasse 1946, Sindermann 1966) which also occurs on the skin. Dempster (1955, 1956) collected some clown fish (*Amphyprion percula*) that had both gills and body covered with *Oodinium* (= *A. ocellatum*?). Aquarists often refer to tegumental infections as "velvet disease." In the present

TABLE 5.

Partial behavior of various fishes when heavily infected by *Amyloodinium ocellatum.*

| Species | Behavior |
| --- | --- |
| *Dasyatis sabina* | Sluggish; irregular beat of spiracles; snout turned up so water could be pumped easier; swimming at surface with snout out of water; coughing to back-flush gills. |
| *Ophichthus gomesi* | Head at top of tank in corner; gasping and squirting water (back-flushing of gills); trying to get out of tank; when weaker sinking to bottom, usually on back. |
| *Anchoa mitchilli* | Gasping; jerky, uncoordinated movements around tank; darting to surface and then sinking vertically with tail down. |
| *Arius felis* | Gasping; spasmodic beat of opercules; head up and body vertical at top of tank, then sinking vertically; on back or side at bottom gasping. |
| *Archosargus probatocephalus* and *Lagodon rhomboides* | Gasping; spasmodic beat of opercules, with mouth almost never fully closed; scraping on objects in tank, and tank bottom. |
| *Bairdiella chrysura* | Gasping; spasmodic beat of opercules; sluggish. |
| *Leiostomus xanthurus* | Gasping; spasmodic beat of opercules; vertical at surface and squirting water (back-flushing of gills). |
| *Micropogonias undulatus* | Gasping; spasmodic beat of opercules; vertical at surface, head up and squirting water (back-flushing of gills); sinking vertically with tail down. |
| *Hypsoblennius ionthas* | Gasping; spasmodic beat of opercules, with mouth almost never fully closed; constant swimming of some specimens; trying to jump out of tank. |
| *Prionotus tribulus* | Constant swimming near surface. |
| *Archirus lineatus* and *Trinectes maculatus* | Gasping; spasmodic beat of opercules; sluggish, little or no darting when prodded; can no longer hold onto tank sides utilizing ventral surface, slide or fall to bottom. |

study, *A. ocellatum* was found on the gills (filaments, arches, rakers), skin, fins, eyes, pseudobranchs, membranes of the branchial cavity and around the teeth; and in nasal passages, esophagus, and intestines of experimentally infected fishes. It was not unusual to find 200 plus trophonts per filament on experimentally infected fish. The cysts (10 to 50) found in the intestine of *Micropogonias undulatus* were not attached, so it is possible they were ingested after being dislodged from the gills. Brown (1934) found a large collection of *A. ocellatum* cysts free in the stomach of *Julis pavo*. Højgaard (1962) said it can be found in the intestines, and noted that in such a location the parasite probably cannot be controlled effectively with copper. In addition, unidentified cysts were found under the epithelium of gill filaments of three specimens of *M. undulatus* that had been treated with the drug "TetraCare Fungi Stop." Other fishes from experimental tanks had numerous small (N = 6) 8.7–20.3 by 10.2–24.8 cysts in their gills. The cysts had no apparent attachment to the gills and no flagellum, but some had a red stigma. Whether these cysts are a resting stage of *A. ocellatum*, a free-living organism, or a different parasitic organism is unknown. Similar cysts were reported by Schäperclaus (1935, 1954) for *Branchiophilus maris* (= *A. ocellatum*).

Brown (1934) listed a series of conditions which were found in association with the occurrence of *A. ocellatum* on the gills, and said (p. 603), "In cases of heavy infection the numbers of parasites would, in themselves, constitute a mechanical cause of death by obstruction of the passage of water over the gill-filaments." Duijn (1967, p. 57) summarized her findings as follows: "The parasites cause haemorrhages [sic], inflammation and necrosis in the gills, which open [the] way to secondary bacterial infections." Nigrelli (1936) detected some infected fish by a pink-tinted mucus secretion on the surface of the body and thought, "This pink color is due possibly to waste products of the parasites, . . ." No analysis of damage to the host has been conducted for the present study.

Heavily infected gills generally lacked the bright coloration of healthy oxygenated blood and appeared light pink. Various tegumental lesions associated with *A. ocellatum* and secondary infections have also been observed. Lom and Lawler (1973) found that *Amyloodinium* sp. on Cyprinodontidae did extensive damage to epithelial cells by the rhizoids pulling out surface regions into villi-like projections which may be severed off from the cell. They suggested that the stomopode might bring host cell material to the phagocytic region of *Amyloodinium* sp. and concluded that "The extensive damage done by a single trophont to many epithelial cells in which its rhizoids are embedded, as well as avid feeding on large lumps of host cell cytoplasm, explains the high pathogenecity of dinoflagellates for fish." It is possible that the "pink-tinted mucous [sic] secretion" noted by Nigrelli (1936), and the damage noted by Brown (1934) are caused by a similar process.

#### *Mariculture Problems*

The occurrence of *A. ocellatum* in closed-system mariculture ventures is a major problem. For example, the Anadromous Fishes Section of the Gulf Coast Research Laboratory lost about 300,000 juvenile (37 to 38 days old) striped bass *Morone saxatilis*, on June 25-26, 1976, because of *A. ocellatum* (see McIlwain 1976b). This was 75 to 80% of the stock on hand. The fish were held in a recirculating system (McIlwain 1976a) consisting of 1000-gallon circular fiberglass tanks containing water (salinity = 5 ppt) which was pumped from a small craft harbor into two holding ponds, and then into the tanks. Apparently the initial infective dinospores were introduced when water was pumped from the harbor into the ponds and then to the tanks. On July 12, 1972, and on July 30, 1975, I examined dying juvenile pompano which were being raised by the

Louisiana Wildlife and Fisheries Commission at Grand Terre, Louisiana; deaths were due to 10 to 30 plus *A. ocellatum* trophonts per gill filament.

Some additional reports of outbreaks of this parasite are those occurring at (1) the Claude Peteet Mariculture Center, Gulf Shores, Alabama (May 25 and October 2-3, 1978), involving *Trachinotus carolinus* (Linnaeus), *Sciaenops ocellata* (Linnaeus), *Morone saxatilis* (Walbaum), and *Lutjanus campechanus* (Poey); (2) the National Marine Fisheries Service laboratory at Galveston, Texas (June 16, 1978), involving *Morone saxatilis*; and (3) the Gulf Coast Research Laboratory at Ocean Springs, Mississippi (June 25 and July 13, 1979), involving *Mugil cephalus* Linnaeus and *Aluterus schoepfi* (Walbaum) which were being held for toxicity tests.


## ACKNOWLEDGMENTS

National Marine Fisheries Service and State of Mississippi grants to Dr. Robin M. Overstreet provided the support for this study; he also gave many suggestions and critically reviewed the manuscript. The following Gulf Coast Research Laboratory personnel assisted in collecting some of the hosts: Clyde Cannette, Dennis Chew, Sherman Cole, Al Glass, Dr. William Hawkins, Dr. Richard Heard, Thomas Henderson, Tim Hendrickson, Monroe Howell, Walter Langley, Tom Mattis, Dr. Thomas McIlwain, Larry Nicholson, Ronnie Palmer, Thomas VanDevender, and Ned Whatley. Some technical assistance was provided by Steven L. Shepard and W. Jeff Tolbert. Richard S. Waller identified many of the hosts. C. E. Dawson kindly identified *Lutjanus analis*.


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Gulf Research Reports

Volume 6 | Issue 4

January 1980

# *Lepidactylus triarticulatus* N. Sp., A New Haustoriid Amphipod from the Northern Gulf of Mexico

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DOI: 10.18785/grr.0604.09

*Gulf Research Reports*, Vol. 6, No. 4, 415–420, 1980.

# *LEPIDACTYLUS TRIARTICULATUS* N. SP., A NEW HAUSTORIID AMPHIPOD FROM THE NORTHERN GULF OF MEXICO

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*ABSTRACT* A new haustoriid amphipod, *Lepidactylus triarticulatus* n. sp., from the northern Gulf of Mexico is described and illustrated. The known range is from northern Padre Island, Texas, to Grand Isle, Louisiana. The species is ecologically plastic. On surf-exposed sandy beaches it is most abundant at the highest intertidal levels, but in fine-grained sands of wave-sheltered localities it occurs throughout the intertidal region into shallow subtidal depths. In central Texas bays it has been collected subtidally at salinities as low as 10 ppt. There are differences in morphological details of peraeopod 7 between the intertidal and subtidal populations which we regard as an ecotypic variation. A provisional generic characterization is given for the genus *Lepidactylus* Say.

## INTRODUCTION

During investigations of the community structure of intertidal macrofauna on Texas sandy beaches, we found an undescribed species of *Lepidactylus* (Order Amphipoda, Family Haustoriidae) to be one of the quantitatively dominant organisms at Malaquite Beach in Padre Island National Seashore. In a recent report of those studies we designated that species *Lepidactylus* sp. 2 (Shelton and Robertson, in press). In the present paper we describe the species. Correct identification of Texas beach fauna has recently assumed increased importance as efforts continue to assess environmental effects of the IXTOC I oil spill.

### Genus *Lepidactylus* Say, 1818

The generic characters of *Lepidactylus* have not been clearly established, as for other haustoriid genera (Bousfield 1973). Probably the type species, *L. dytiscus* Say, was not described in sufficient detail, and therefore, it requires redescription. *Lepidactylus dytiscus* occurs on the Atlantic coast from the York estuary, Chesapeake Bay (Bousfield, personal communication) to northern Florida (Dexter 1967). There are no published descriptions of any other species. Bousfield (1973) noted that *Lepidactylus* resembles *Haustorius* but lacks the projecting abdominal shelf, and mentioned some other diagnostic features in a key to the genera. The following provisional generic characterization is based on Bousfield (1973), and on our own observations of *L. dytiscus* (specimens from Town Creek, South Carolina) and an undescribed Texas species, in addition to the species herein described.

Body broad-fusiform, small to medium size. Head broadest medially; rostrum moderate. Pleosome narrowing behind peraeon 7; hind margin of pleosome segment 3 not projecting as a lobe or shelf overhanging the urosome; side plate 3 rounded behind. Urosome reduced; urosome 2 short.

Antenna 1, accessory flagellum 2–3 segmented. Antenna 2, peduncular segment 5 deep, not lobate behind. Mandibular palp long, segment 3 with several marginal comb spines. Maxilla 1, coxal baler lobe well developed. Maxilla 2, outer plate large, broad, not narrowly lunate. Maxilliped plates broad; palp segment 3 stout, geniculate.

Gnathopod 1 simple, segment 5 expanded. Gnathopod 2 minutely chelate. Peraeopods 3 and 4 similar, 3 somewhat larger. Peraeopod 3, segment 5 posterior lobe short, rounded distally.

Uropods all biramous. Uropod 1, rami subequal or inner slightly longer, inner ramus with marginal setae and terminal spines. Uropod 2, rami and peduncle strong, outer ramus somewhat longer than inner. Uropod 3, outer ramus with 2 subequal segments. Telson deeply incised; lobes apically and laterally spinose or spinose and setose.

*Remarks:* Although it may be difficult to separate juvenile *Haustorius* spp. from *Lepidactylus*, we are convinced that *Lepidactylus* is a valid genus distinct from *Haustorius*. Western Atlantic adult *Haustorius* and *Lepidactylus* appear to differ generically in the following characteristics:

1. The hind margin of pleosome segment 3 projects as a lobe or shelf overhanging the urosome in *Haustorius*, but not in *Lepidactylus*.
2. The outer plate of maxilla 2 is elongated and narrowly lunate in *Haustorius*; in *Lepidactylus* it is relatively broader, not narrowly lunate.
3. The maxilliped plates are relatively narrower in *Haustorius*.
4. The posterior lobe of peraeopod 3, segment 5 is ovally elongated in *Haustorius*; in *Lepidactylus* this lobe is short and rounded.
5. The accessory flagellum of antenna 1 of *Haustorius* is 3–5 segmented. In a key to genera of Haustoriidae, Bousfield (1973) gave 3–4 segments for the accessory flagellum of *Lepidactylus*; however, in the *Lepidactylus* spp. we examined, it was 2–3 segmented.

### *Lepidactylus triarticulatus* New Species

Holotype and paratype material. Malaquite Beach, Padre Island National Seashore, Texas, fine intertidal sand, July

Manuscript received April 23, 1980; accepted August 4, 1980.

1976 to June 1977: several thousand males, females, immatures.

*Other Study Material:* Copano Bay, Texas, behind Sea Gun Motel, fine muddy sand, shallow subtidal, April 20, 1975, Hugh Goodrich: several males, females; Copano Bay, Texas, near base of bridge behind Sea Gun Motel, fine muddy sand, depth 0.3 to 0.6 m, salinity 9.5 ppt, May 24, 1976: several males, females; Matagorda Bay at Port O'Connor, Texas, fine muddy sand of sheltered subtidal flat, November 26, 1976, Scott T Clark: 2 females, 3 immatures; Port Bolivar, Texas, wave-sheltered fine sand 1 km north of jetty, shallow subtidal depths, October 17, 1975: several males, females; Grand Isle, Louisiana, east end of island, fine wave-sheltered sand behind a breakwater, at various intertidal levels, and outside the breakwater subtidally to 0.2 m depth, April 6, 1977: numerous males, females; same locality and date, surf-exposed Gulf beach at Grand Isle State Park, only at high intertidal levels: numerous males, females.

*Holotype:* Ovigerous female, 4.0 mm, deposited in the U.S. National Museum (USNM 181369).

*Paratypes:* Two females (ovig.), two males, deposited in the U.S. National Museum (USNM 181370); two females (ovig.), two males, deposited in the National Museum of Natural Sciences (Canada).

*Etymology:* The specific epithet *triarticulatus* refers to the three-segmented accessory flagellum of antenna 1.

#### *Diagnosis*

Antenna 1, accessory flagellum 3-segmented. Antenna 2, flagellum 6-segmented. Peraeopod 4, coxal plate longer than broad. Peraeopod 7, segment 2 posterior border naked; segment 4 tapering distally to subacute apex; segment 5 posterior border lacking setae above lower angle; segment 6 stout, broadest medially, length about twice the width. Uropod 1, peduncle with 1–2 small spines proximally, naked between these and interramal spines.

#### *Description*

Female (ovig.), 4.0 mm Head (Figure 1) broader than long; rostrum broadly subacute. Pigmented eyes not evident in preserved material.

Antenna 1 (Figure 2): accessory flagellum 3-segmented; flagellum 6-segmented.

Antenna 2 (Figure 3): flagellum 6-segmented.

Upper lip (Figure 6): broad; apical margin shallowly indented.

Lower lip (Figure 7): outer lobes large; inner lobes broad at apex.

Mandible (Figure 5): incisor bi- or minutely tri-dentate; lacinia acute; 6 blades; palp segment 3 with 9 proximal marginal comb spines.

Maxilla 1 (Figure 8): outer plate apical margin with 4 blunt spines and 10 acute teeth spines; inner plate with 8 setae.

Maxilla 2 (Figure 9): outer plate with 21 setae distal to comb teeth.

Maxilliped (Figure 4): plates and palp broad; terminal segment of palp stout, distal margin short.

Gnathopod 1 (Figure 15): coxa, posterior angle with numerous short setae and 4 plumes; segment 5 stout, heavily setose posteriorly.

Gnathopod 2 (Figure 16): coxa narrow, posterior angle with 1 naked seta and 5 plumes; segments 2, 5, and 6 slender; female brood plate with 2–4 setae distally.

Peraeopod 3 (Figure 17): coxa broad, semilunate; posterior angle with 2 naked setae distally and 6 plumes; segment 2, length about 2.3 times width; segment 4 stout, broadening distally; segment 5, posterior lobe short, rounded, armed with circlet of 11 blunt spines and 4 plumes; segment 6 with 1 seta and 12 blunt or minutely bifid spines; female brood plate with 19–23 setae.

Peraeopod 4 (Figure 18): coxal plate distinctly longer than broad; posterior lobe broadly and obtusely triangular; segment 2, length 2.25 times width; segment 4 stout, expanding distally; segment 5 posterior lobe rounded, with 6 plumes and circlet of 6 spines; segment 6 with 4 plumes and 9 spines; female brood plate with 18 long setae.

Peraeopod 5 (Figure 19): posterior coxal lobe marginally setose, deeper than anterior lobe; segment 2 broader than long; segments 4 and 5 broader than long; segment 6 linear, anterior margin with 2 spine groups.

Peraeopod 6 (Figure 20): coxal margin rounded posteriorly, with numerous short plumes; segment 2 nearly as broad as long; segment 4 broadest distally, with few lateral facial spines; segment 5 subquadrate, with few lateral facial spines, with a shallow U-shaped indentation near lower anterior border; segment 6 stout, shorter than 5, with 3 posterior spine clusters proximal to distal cluster.

Peraeopod 7 (Figure 21): posterior coxal lobe oval, with short plumes along lower border; segment 2 orbicular, posterior border naked; segment 4 tapering posteriorly to narrow, subacute apex, lacking a well defined posterior border; one plume and two smaller setae distally before apex; spines at apex and along lower distal border; segment 5 longer than broad, posterior distal border relatively straight; no spines or setae above lower posterior angle; segment 6 stout, broadest medially, about twice as long as broad.

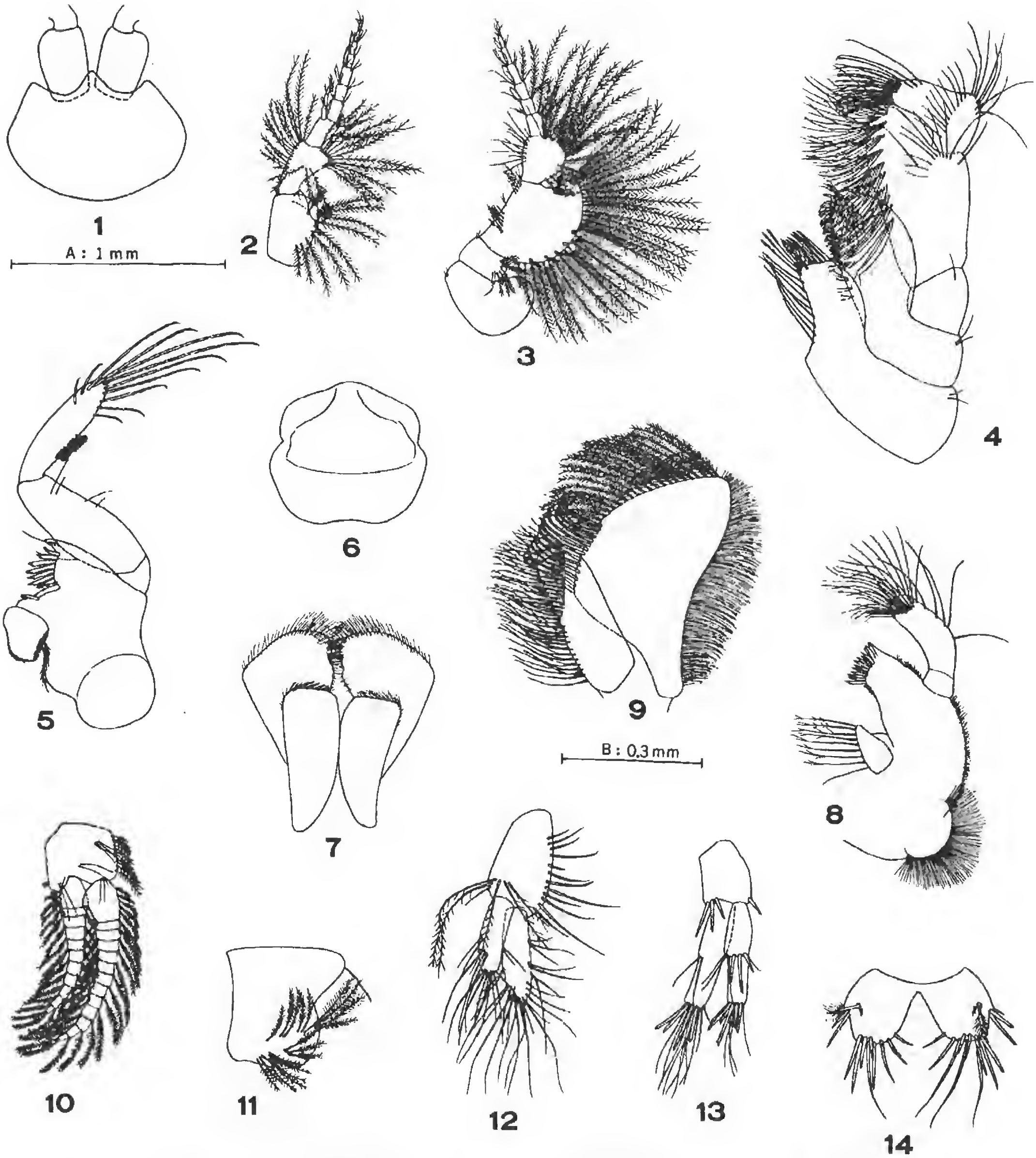
Pleosome side plate 3 (Figure 11): lower border straight, evenly rounding posteriorly; 3 groups of plumes near lower border, about 4 groups of facial plumes, and a large plume at upper posterior border.

Pleopods (Figure 10): peduncle broader than long, with outer marginal plumes; rami slender; inner 11-segmented, outer longer and 14-segmented.

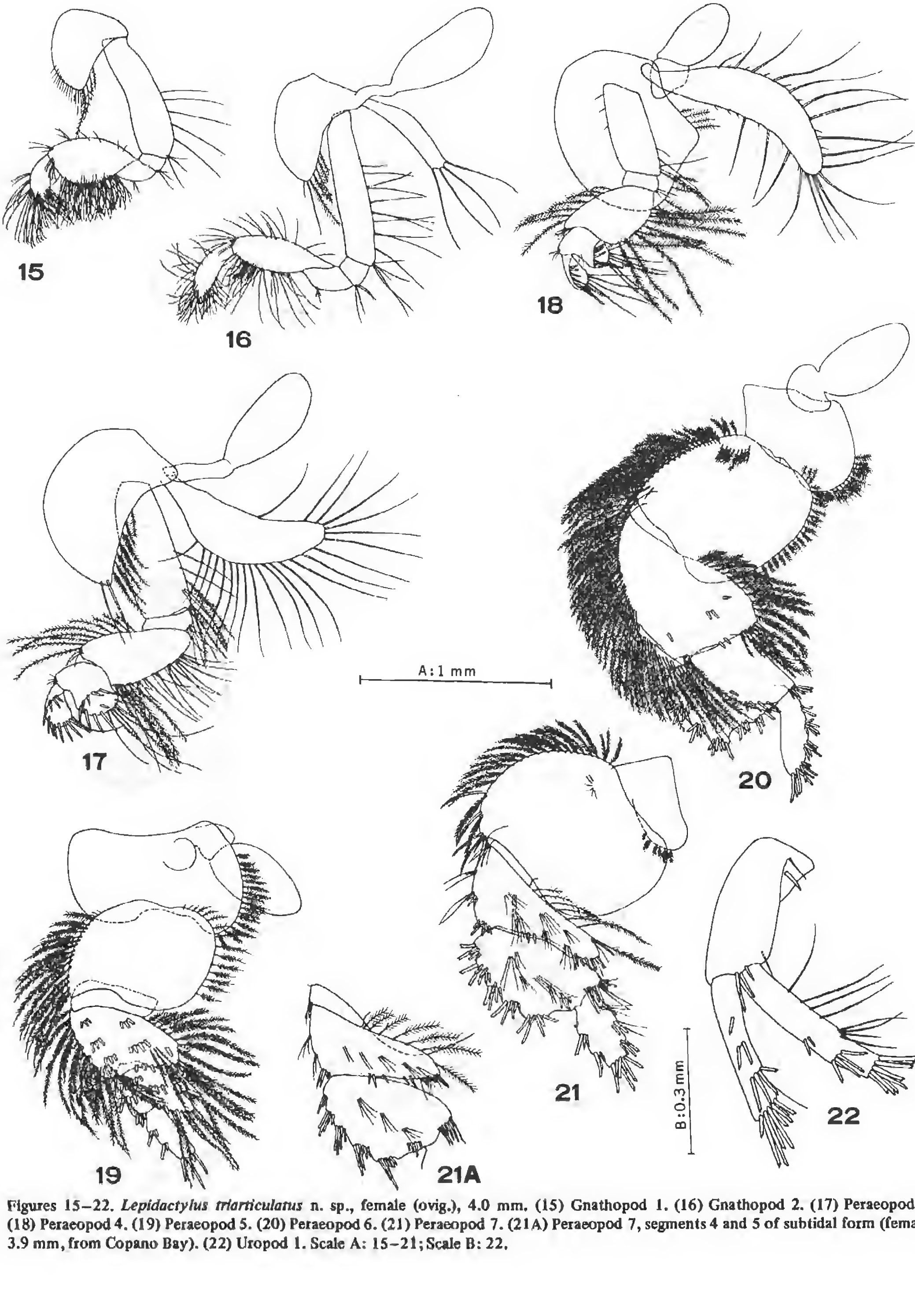
Uropod 1 (Figure 22): peduncle stout, with 1 small seta and 1–2 small spines proximally, naked between these and the interramal spines; inner ramus slightly longer than outer.

Uropod 2 (Figure 12): peduncle slightly longer than outer ramus, the latter somewhat longer than inner ramus.

Uropod 3 (Figure 13): peduncle short; rami subequal;




Figures 1–14. *Lepidactylus triarticulatus* n. sp., female (ovig.), 4.0 mm. (1) Head. (2) Antenna 1. (3) Antenna 2. (4) Maxilliped. (5) Mandible. (6) Upper lip. (7) Lower lip. (8) Maxilla 1. (9) Maxilla 2. (10) Pleopod 1. (11) Pleosome side plate 3. (12) Uropod 2. (13) Uropod 3. (14) Telson. Scale A: 1–3, 10–11; Scale B: 4–9, 12–14.




Figures 15–22. *Lepidactylus triarticulatus* n. sp., female (ovig.), 4.0 mm. (15) Gnathopod 1. (16) Gnathopod 2. (17) Peraeopod 3. (18) Peraeopod 4. (19) Peraeopod 5. (20) Peraeopod 6. (21) Peraeopod 7. (21A) Peraeopod 7, segments 4 and 5 of subtidal form (female, 3.9 mm, from Copano Bay). (22) Uropod 1. Scale A: 15–21; Scale B: 22.

the two segments of outer ramus subequal.

Telson (Figure 14): broadly and deeply cleft nearly to base; each lobe with one lateral group of 2–3 spines; apically with 9–10 spines (some more elongated and setiform).

Male, 4.2 mm. Peraeopod 3, segment 2 length about 2.0 times width. Peraeopod 4, segment 2 length about 1.7 times width. Peraeopod 5, segments 4 and 5, respectively, with 22 and 15 blunt lateral facial spines. Peraeopod 6, segments 4 and 5 each with about 9 blunt lateral facial spines. Peraeopod 7, segment 4 with one plume and one smaller seta distally before apex.

*Remarks:* There is sexual dimorphism in the greater stoutness of segment 2 of peraeopods 4 and 5 in males, and in their somewhat larger number of lateral facial spines on the above mentioned segments of peraeopods 5 and 6. However, dimorphic differences are not as significant in *L. triarticulatus* n. sp. as they are in other *Lepidactylus* spp. that we have examined.

We find apparently consistent morphological differences between the intertidal and subtidal populations of both sexes in details of peraeopod 7. The specimens collected above the waterline at Grand Isle agree with the Malaquite Beach material in that segment 4 has one or two shorter setae in addition to a plume distally before the apex, and the posterior distal border of segment 5 is relatively straight, with little arch at the distal angle (Figure 21). The subtidal specimens from Grand Isle, Bolivar, Copano Bay, and Port O'Connor differ in that segment 4 has only a plume distally before the apex and the posterior border of segment 5 is more convexly arched toward the distal angle (Figure 21a). In other respects the intertidal and subtidal forms are quite similar. For the present, at least until the variation throughout the range and habitats occupied by the species can be more fully evaluated, we regard these differences as ecotypic variation in an ecologically and morphologically plastic species.

*Ecology:* At the type locality, a surf-exposed, fine-grained sand beach, *L. triarticulatus* n. sp. was most abundant at the highest intertidal levels. During warm months it was rather sharply zoned, with only a narrow region of overlap with populations of an undescribed *Haustorius* sp. which dominated lower high- and mid-tide levels (for quantitative data see Shelton and Robertson, in press). On surf-exposed Gulf beaches *L. triarticulatus* is most abundant at, or restricted to, the highest intertidal levels, possibly due to competition with the co-occurring *Haustorius* sp. In wave-sheltered fine sands it occurs throughout the intertidal region into shallow subtidal depths. The species is euryhaline, inhabiting salinities as low as 10 ppt in central Texas bays.

*Range:* We have not found this species in collections at South Padre Island, or on wave-exposed mainland beaches of the northeastern Texas coast at Sea Rim State Park and near High Island, where it is replaced by a different, undescribed species of *Lepidactylus.* Thus the known range of *L. triarticulatus* n. sp. to date is from northern Padre Island, Texas, to Grand Isle, Louisiana, with an apparent discontinuous distribution along the northeastern Texas coast.

### KEY TO THE SPECIES

Of the material we have examined, *L. triarticulatus* n. sp. is most similar to a northeastern Gulf form being described by Dr. E. L. Bousfield (personal communication). The northeastern Gulf form appears to be somewhat larger (length 5.1 to 6.9 mm for six males and four females provided to us by Dr. Bousfield from Little Deer Island, Mississippi), and there are minor differences in numbers of certain setae, spines, and segments. We include this form in the key below to assist eastern Gulf workers, with the stipulation that our observations are preliminary and incomplete. Determination of the specific status of this *Lepidactylus* must await detailed analysis of populations east of the Mississippi River.

### PRELIMINARY KEY TO THE ATLANTIC AND GULF COAST SPECIES OF *LEPIDACTYLUS*

1. Peraeopod 7, segment 2 posterior border setose; segment 5 posterior border with 1 setae group above lower angle; antenna 1, accessory flagellum 2-segmented . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . *L. dytiscus* Say

   Peraeopod 7, segment 2 posterior border naked; segment 5 posterior border without setae above lower angle; antenna 1, accessory flagellum 2- or 3-segmented . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 2

2. Antenna 1, accessory flagellum 2-segmented; peraeopod 7, segment 4 posterior border obtusely truncated in males, shallowly oblique in females; segment 6 slender, linear, length 2.3 to 2.5 times width. . . . . . . . . . . . . . . . . . . . . . *L.* undescribed species (reported as *Lepidactylus* sp. 1 by Shelton and Robertson, in press)

   Antenna 1, accessory flagellum usually 3-segmented (may be 2-segmented in immatures); peraeopod 7, segment 4 tapering distally to subacute apex; segment 6 stout, broadest medially, length about 2.0 times width . . . . . . . . . . .3

3. Antenna 2, flagellum 6-segmented; length to 4.8 mm . . . . . . . . . . . . . . . . . . . . . . . . . . . . *L. triarticulatus* n. sp.

   Antenna 2, flagellum 7-segmented; length to 6.9 mm . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . *L.* undescribed form (description in preparation by Dr. E. L. Bousfield)

**ACKNOWLEDGMENTS**

We thank Robert G. Whistler, chief naturalist of Padre Island National Seashore, for allowing access to the restricted portion of Malaquite Beach; Dr. E. L. Bousfield for providing information concerning the genus *Lepidactylus*, and specimens of *L. dytiscus* and the eastern Gulf form; and the following persons for assistance in collecting the material examined: Scott Clark, Hugh Goodrich, Dr. Keith Hansen, George Linney, Jane Robertson, and Julie Shelton.

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## Gulf Research Reports

Volume 6 | Issue 4

January 1980


# Diatoms in the Gills of the Commercial White Shrimp


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DOI: 10.18785/grr.0604.10

*Gulf Research Reports*, Vol. 6, No. 4, 421–422, 1980.

# SHORT COMMUNICATIONS

## DIATOMS IN THE GILLS OF THE COMMERCIAL WHITE SHRIMP

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*ABSTRACT* A white shrimp from Galveston, Texas, is the first reported case of a crustacean internally infected by a diatom. Even though more than one species occurred in debris on and between gill filaments, only individuals of *Amphora* sp. occurred within gills. To determine if a related diatom would easily reproduce within the shrimp and cause a host-response similar to that observed, we injected cultured specimens of *A. coffaeformis* into white shrimp. Under the experimental conditions, individuals of that species did not divide, but they elicited an extensive melanistic host-response.

Gills of a single specimen of the white shrimp *Penaeus setiferus* from Galveston, Texas, harbored numerous melanistic regions. This particular specimen, the first crustacean reported to be infected in the hemocoel with algae, had been collected from the natural environment and maintained along with others during a project dealing with shrimp maturation. Soon after death, it was fixed in Carnoy's II solution and sent to us for identification of the agent or agents eliciting the melanistic response. Jorge Leong, who forwarded the specimen, noted no similarly affected shrimp at his laboratory at that time.

Gross examination of a stained preparation (Van Cleave's hematoxylin) of a few gills revealed clusters of diatoms associated with deposits of presumed melanin. These clusters consisted of *Amphora* sp. On the other hand, individuals of *Amphora* sp., *Nitzschia* spp., and *Achanthes* spp. (including *A. exigua*) occurred in debris on and between filaments. Additionally, an apostomatid ciliate occurred within a few filaments.

Sectioned material showed several sites, primarily in the tips of filaments, where hemocytes had apparently encircled diatoms. In the voluminous hemolymph-filled space of the afferent channel of one gill adjacent to its lamellar junctions, *Amphora* sp. occurred in large clusters. Stained internal structures within the diatoms suggest that most were alive at the time of fixation. Apparently *Amphora* sp. grew and reproduced within the shrimp, since individual organisms in the afferent channel ranged from small to large and exhibited a variety of shapes. A heterogeneous debris-like substance surrounded most of the internal clusters of diatoms, possibly resulting from their metabolic wastes. The substance contrasted with the lightly stained hemolymph by staining red and violet with Taylor's technique for bacteria and blue and violet with the Ziehl-Neelsen method for bacteria (Luna 1968). In contrast to that in most shrimp, the hemolymph in this particular shrimp had a fibrinous consistency.

Manuscript received May 12, 1980; accepted July 2, 1980.

In an effort to determine if diatoms easily reproduce in the white shrimp, we injected saline with cultured *Amphora coffaeformis* into either the hemocoel or abdominal musculature of 50 shrimp. We used *A. coffaeformis* since it closely resembled the unidentified species present in the shrimp from Texas. Within an hour, most injected diatoms concentrated in the gill region. By 24-hour postinoculum (PI), we detected melanization as yellowish-brown foci. These regions acquired a dark color by day 2. By day 4 they became more numerous, larger, and darker. Seldom did more than a few individual diatoms occur together, suggesting their failure to reproduce. Nevertheless, the inoculated shrimp died sooner than saline-injected counterparts used as controls. When only a few individual diatoms were introduced into shrimp in a follow-up experiment, no aggregations became apparent after 7, 14, or 21 days PI.

We conclude that the single infected shrimp from Texas probably represents an abnormal or accidental case. Possibly, recently eaten diatoms passed or were forced through a damaged or filled alimentary tract. In any event, the host apparently encapsulated diatoms at a slower rate than some individuals could multiply. In the experimental shrimp a factor such as the strain of diatom, health or resistance of shrimp, or other influence may have inhibited reproduction of the diatom.

Once certain diatom species gain entrance into a crustacean's hemocoel, hemolymph might provide a good culture medium. *Amphora* spp. are known to be remarkably versatile in their requirements for growth. Cooksey and Chansang (1976) reported different requirements for three different heterotrophic cultures of *Amphora* spp. Moreover, some species withstand harsh environments. *Amphora coffaeformis* adjusts by establishing resting cells which can rapidly reestablish to the logarithmic stage given favorable conditions (Anderson 1975).

Melanization and the cellular inflammatory response in penaeids and other arthropods have already been documented. Lightner and Redman (1977) reported that a variety of pathological conditions, organisms, heavy metals, and

unknown agents elicited the response. Babu and Hall (1974) using a variety of histochemical methods demonstrated that the pigment was indeed melanin, and Solangi and Lightner (1976) described the progression of a hemocytic response in shrimp gills.

Another diatom has been observed in an arthropod hemocoel. Laird, et al. (1976) reported that a single larva of *Culex theileri* contained an abundance of *Cocconeis placentula* var. *euglypta*. Algae not in the hemocoel also affect crustaceans, both deleteriously and benignly. As an extreme example of harm, Lightner (1978) described severe acute hemocytic enteritis with secondary bacterial infections in reared blue shrimp. That disease, which greatly affects the production of shrimp, apparently resulted when the shrimp fed on a toxic blue-green alga (D. V. Lightner, personal communication).

## ACKNOWLEDGMENT

We wish to thank Jorge K. Leong of the National Marine Fisheries Service in Galveston, Texas, for sending the preserved infected shrimp and O. Roger Anderson of Lamont-Doherty Geological Observatory of Columbia University for sending cultured *Amphora coffaeformis*. Ronnie Palmer and Roswitha Buxton provided technical assistance. The study was conducted in cooperation with the U.S. Department of Commerce, NOAA, National Marine Fisheries Service, under PL 88–309 Project No. 2–325–R.

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# Gulf Research Reports

Volume 6 | Issue 4

January 1980


## Occurrence and Seasonality of *Perkinsus marinus* (Protozoa: Apicomplexa) in Mississippi Oysters


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DOI: 10.18785/grr.0604.11

*Gulf Research Reports*, Vol. 6, No. 4, 423–425, 1980.

# OCCURRENCE AND SEASONALITY OF *PERKINSUS MARINUS* (PROTOZOA: APICOMPLEXA) IN MISSISSIPPI OYSTERS

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*ABSTRACT* Oysters from four reefs in Mississippi Sound, sampled over a period of 25 months, were found to have a low prevalence of the protozoan parasite *Perkinsus marinus*. The greatest values were 80% prevalence, and 0.88 weighted incidence recorded for oysters from Biloxi Bay, Mississippi.

## INTRODUCTION

*Perkinsus marinus*, an oyster parasite, has been suggested as a cause of massive mortalities in Mississippi oysters (Gunter and Demoran 1970, 1971; Gunter et al. 1974; Overstreet 1978). Although Owen (1950) did not find the parasite in Mississippi oysters, it is known to occur (Mackin 1962; Ray 1954; McGraw 1980; Demoran, personal communication). *Perkinsus marinus*, previously identified as *Dermocystidium marinum* and *Labyrinthomyxa marina*, respectively, was first described from Louisiana oysters by Mackin et al. (1950). In the Gulf of Mexico, it has been reported from Texas (Hofstetter 1977), Alabama (Beckert et al. 1972), and Florida (Dawson 1955, Quick and Mackin 1971). Since no data were available on the seasonality and occurrence of the infection in Mississippi oysters, the present study was conducted.

## MATERIALS AND METHODS

Twenty oysters from each of four stations (a lagoon on Horn Island, Graveline Bayou, a closed reef in Biloxi Bay, and a commercial reef at Henderson Point near Pass Christian) were collected monthly from March 1978 to March 1980. The presence of *P. marinus* was detected by culturing a piece of the anterior oyster mantle in fluid thioglycollate fortified with antibiotics for 14 days using the procedure of Ray (1952, 1966). Its prevalence and weighted incidence (as defined by Ray [1954]) were determined according to the procedures of Ray (1954) and Mackin (1962). Hydrographic data including temperature, determined to the nearest degree Celsius, and salinity, determined to the nearest part per thousand (ppt) with an American Optical total solids refractometer, were collected monthly for each station.

## RESULTS

The parasite never reached the epizootic level in oysters from any station at any time during this study (Table 1). When *P. marinus* reaches a weighted incidence of 2.00 in the live oyster population, it is considered to be epizootic (Mackin 1962). Oysters from the Biloxi Bay station were found to be infected in 23 of the 25 sampling periods, and during October of 1979, had the greatest weighted incidence (0.88) and prevalence (80%) recorded for this study. Biloxi Bay also had the greatest average weighted incidence (0.23) and average prevalence (22.4%) for the 25-month period; Pass Christian had the smallest average weighted incidence (0.10) and average prevalence (9.7%) for the same period. The prevalence exceeded 50% in only four of the samples: two from Biloxi Bay (April 1978–60%, and October 1978–80%), and two from Horn Island (October 1978–60%, and April 1979–53%).

The highest recorded temperature (34°C) occurred at the Biloxi Bay station; the lowest temperature (6°C) occurred at the Horn Island station. The highest salinity (32.0 ppt) occurred at the Horn Island station; the lowest salinity (0.0 ppt) occurred at the Graveline Bayou station.

## DISCUSSION

The protozoan *P. marinus* was seldom prevalent for oysters from any station sampled. The similarity of hydrographic conditions for all stations might explain the similarity in infections. Sampling should be continued over several years to encompass varying hydrographic conditions. Lack of an epizootic during this study may be due to the absence of a major foci of infection. There is no evidence to suggest that the lack of epizootic levels was caused by disease resistance in Mississippi oysters. Recent interest has been expressed by an agency of the State of Mississippi in planting seed oysters and moving oysters for restocking and relaying; however, care should be taken to avoid importing heavily diseased oysters. Relayed oysters should be monitored and assayed for *P. marinus*.

## ACKNOWLEDGMENTS

John Supan aided in field collection, and Juanita Ferguson reviewed the paper. This project was supported in part by the Mississippi Department of Wildlife Conservation, Bureau of Marine Resources, under Contract No. CO–ST–79–018.

Manuscript received Sept. 12, 1980; accepted Sept. 23, 1980.

TABLE 1.

Occurrence of *Perkinsus marinus* in Mississippi oysters.

| Month | 1978 | | | | | | | | | | 1979 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar |
| **Biloxi Bay** | | | | | | | | | | | | | |
| Temperature °C | 21 | 19 | 29 | 34 | 32 | 29 | 26 | 23 | 18 | 11 | 7 | 13 | 22 |
| Salinity ppt | 22 | 12 | 6 | 6 | 8 | 16 | 18 | 22 | 26 | 20 | 16 | 4 | 4 |
| Prevalence % | 0 | 60 | – | 40 | 20 | 15 | 35 | 80 | 40 | 5 | 5 | 10 | 10 |
| Weighted Incidence | 0 | 0.35 | – | 0.29 | 0.38 | 0.25 | 0.30 | 0.88 | 0.38 | 0.05 | 0.05 | 0.08 | 0.05 |
| **Graveline** | | | | | | | | | | | | | |
| Temperature °C | 19 | 24 | 22 | 30 | 32 | 28 | 25 | 23 | 17 | 11 | 8 | 10 | 14 |
| Salinity ppt | 21 | 15 | 18 | 6 | 11 | 16 | 19 | 24 | 21 | 12 | 15 | 2 | 5 |
| Prevalence % | 0 | 0 | 0 | 20 | 20 | 25 | 40 | 50 | 40 | 35 | 0 | 0 | 0 |
| Weighted Incidence | 0 | 0 | 0 | 0.10 | 0.23 | 0.15 | 0.55 | 0.38 | 0.30 | 0.30 | 0 | 0 | 0 |
| **Pass Christian** | | | | | | | | | | | | | |
| Temperature °C | 14 | 22 | 22 | 28 | 28 | 28 | 27 | 23 | 17 | 11 | 10 | 15 | 19 |
| Salinity ppt | 18 | 14 | 17 | 12 | 18 | 14 | 18 | 18 | 18 | 15 | 16 | 5 | 5 |
| Prevalence % | 0 | 0 | 10 | 0 | 5 | 15 | 30 | 40 | 10 | 30 | 5 | 0 | 5 |
| Weighted Incidence | 0 | 0 | 0.10 | 0 | 0.05 | 0.30 | 0.25 | 0.53 | 0.08 | 0.12 | 0.05 | 0 | 0.03 |
| **Horn Island** | | | | | | | | | | | | | |
| Temperature °C | – | 22 | 24 | 30 | 24 | 30 | – | 14 | 19 | 12 | 12 | 6 | 16 |
| Salinity ppt | – | 22 | 16 | 12 | 22 | 25 | 22 | 28 | 32 | 24 | 26 | 11 | 14 |
| Prevalence % | – | 0 | 5 | 5 | 37 | 0 | – | 60 | 25 | 6.6 | 0 | 0 | 10 |
| Weighted Incidence | – | 0 | 0.05 | 0.03 | 0.39 | 0 | – | 0.55 | 0.25 | 0.12 | 0 | 0 | 0.05 |

| Month | 1979 | | | | | | | | | 1980 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Avg |
| **Biloxi Bay** | | | | | | | | | | | | | |
| Temperature °C | 20 | 23 | 29 | 32 | 31 | 25 | 21 | 12 | 12 | 13 | 13 | 17 | 21.3 |
| Salinity ppt | 10 | 8 | 14 | 10 | 16 | 8 | 19 | 10 | 22 | 20 | 20 | 5 | 13.7 |
| Prevalence % | 2.5 | 5 | 35 | 20 | 30 | 15 | 40 | 25 | 25 | 10 | 5 | 5 | 22.4 |
| Weighted Incidence | 0.01 | 0.03 | 0.25 | 0.25 | 0.45 | 0.10 | 0.45 | 0.38 | 0.22 | 0.18 | 0.03 | 0.03 | 0.23 |
| **Graveline** | | | | | | | | | | | | | |
| Temperature °C | 19 | 25 | 30 | 30 | 32 | – | 18 | 17 | 10 | – | 15 | 18 | 20.7 |
| Salinity ppt | 0 | 2 | 10 | 0 | 10 | 8 | – | 12 | 10 | 3 | 8 | 22 | 11.3 |
| Prevalence % | 5 | 2.5 | 0 | 5 | 5 | 15 | 5 | 15 | 30 | 20 | 5 | 5 | 13.7 |
| Weighted Incidence | 0.30 | 0.03 | 0 | 0.03 | 0.05 | 0.25 | 0.10 | 0.13 | 0.23 | 0.10 | 0.03 | 0.03 | 0.13 |
| **Pass Christian** | | | | | | | | | | | | | |
| Temperature °C | 20 | 26 | 29 | 29 | 29 | 23 | 20 | 18 | 9 | – | 13 | 18 | 20.8 |
| Salinity ppt | 5 | 0 | 8 | 6 | 14 | 14 | 22 | 20 | 10 | 15 | 10 | 4 | 12.6 |
| Prevalence % | 10 | 0 | – | 5 | 10 | – | 37.5 | 0 | 0 | 0 | 0 | – | 9.7 |
| Weighted Incidence | 0.05 | 0 | – | 0.03 | 0.05 | – | 0.50 | 0 | 0 | 0 | 0 | – | 0.10 |
| **Horn Island** | | | | | | | | | | | | | |
| Temperature °C | 25 | 26 | 24 | 28 | – | – | 23 | 17 | 20 | 15 | 15 | 19 | 20.0 |
| Salinity ppt | 10 | 13 | 18 | 11 | – | – | 24 | 10 | – | 22 | 15 | 12 | 18.5 |
| Prevalence % | 53 | 30 | 35 | 15 | 30 | – | 5 | 0 | 10 | 10 | 0 | 15 | 16.0 |
| Weighted Incidence | 0.37 | 0.35 | 0.30 | 0.18 | 0.25 | – | 0.01 | 0 | 0.08 | 0.05 | 0 | 0.12 | 0.14 |

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# Gulf Research Reports

Volume 6 | Issue 4

January 1980

Prevalence of *Fimeria funduli* (Protozoa: Eimeriidae) in the Longnose Killifish *Fundulus similis* from Horn Island, Mississippi

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DOI: 10.18785/grr.0604.12

*Gulf Research Reports*, Vol. 6, No. 4, 427–428, 1980.

# PREVALENCE OF *EIMERIA FUNDULI* (PROTOZOA: EIMERIIDAE) IN THE LONGNOSE KILLIFISH *FUNDULUS SIMILIS* FROM HORN ISLAND, MISSISSIPPI[1]

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*ABSTRACT* *Eimeria funduli* occurred in *Fundulus similis* from Horn Island, Mississippi, during 1980, in contrast with its apparent absence during 1978 and 1979. Prevalence of the parasite appears to be related to the unusually low salinity in Mississippi Sound, and in ponds and off the beaches of Horn Island. The low salinity may have promoted the migration of infective intermediate hosts from inshore waters to the island.

## INTRODUCTION

Infections of *Eimeria funduli* Duszynski, Solangi, and Overstreet 1979, a pathogenic hepatic coccidian of killifishes, has reached panzootic proportions in specific areas (Duszynski et al. 1979, Solangi and Overstreet 1980). Even though the parasite commonly infected the Gulf killifish *Fundulus grandis* Baird and Girard, in Ocean Springs, Mississippi, Solangi and Overstreet (1980) reported only a limited occurrence of this coccidian in the longnose killifish *Fundulus similis* (Baird and Girard) caught in the same area. Solangi and Overstreet did not observe any infections in about 75 individuals of *F. similis* collected during 1978–1979 from ponds and beaches of Horn Island, an island about 10 km south of Ocean Springs that separates the estuarine waters of the Mississippi Sound from the high-salinity waters of the Gulf of Mexico. This paper reports the prevalence of the coccidian in *F. similis* collected from Horn Island at least a year later, and discusses the various ecological factors that may have contributed to the spreading of the parasite into that area.

## MATERIALS AND METHODS

Using a seine and a cast net, samples of *Fundulus similus* were obtained from a lagoon on the north side of Horn Island. The collection period was from June 3 to August 13, 1980. Fish were measured (total length) and sexed, and livers were examined microscopically for the parasite by fresh squash preparations.

## RESULTS

Of the 100 fish examined, only 15 of 56 males and 5 of 44 females were infected with *Eimeria funduli*. When separated into size groups, 65 fish were greater than 87 mm long, and 29% of those were infected. Except for one male, all infected fish had a total length of 88 mm or greater. In all fish that were infected, oocysts had developed sporozoites.

## DISCUSSION

The most probable explanation for the presence of *Eimeria funduli* in livers of *Fundulus similis* on Horn Island during 1980, in contrast with its absence during 1979 and earlier, appears to be related to the availability of the infective intermediate host. The grass shrimp *Palaemonetes pugio* Holthuis and possibly other crustaceans serve as intermediate hosts; to complete the life cycle, an infective stage in the intermediate host has to be eaten (see Solangi and Overstreet 1980). Although no individuals of *P. pugio* were collected concurrently with *F. similis* in June through August, numerous infected *Fundulus grandis* occurred in the lagoon during the sampling period, but were not collected from the lagoon during 1977 to 1979. Even though *F. grandis* occurred on the island, Franks (1970) reported that this species constituted only 0.5% of total fish caught on Horn Island and did not occupy the lagoon (station 10) during his 2-year sampling period from 1965 through 1966. The migration of the intermediate host and *F. grandis* from inshore waters to the island probably took place in April when unusually low salinities occurred in Mississippi Sound, and in ponds and off the beaches of Horn Island. Salinity data maintained by the Parasitology and Fisheries sections of the Gulf Coast Research Laboratory show that the salinity during April 1980 in Mississippi Sound and at Horn Island ranged from 0 to 1.0 ppt and 3.5 to 8.0 ppt, respectively. These values are low when compared to those of previous years. During the period from 1977 to 1979, the salinity in Mississippi Sound for April fluctuated from 4.0 to 8.0 ppt, and for Horn Island from 7.0 to 28.0 ppt, with values for Horn Island frequently being above 15.0 ppt.

Because it takes about 60 days for sporozoites to develop at 24°C (see Solangi and Overstreet 1980), the presence of sporulated oocysts in livers of infected *F. similis* also suggests that infections occurred during April or earlier. However, because of the advanced stage of the infection, it is possible that the infected *F. similis* from the island were actually migrants from the inshore stock. The reason why most *F. similis* over 87 mm were infected appears to be the ability of large fish to feed on grass shrimp. Individuals of *F. similis* that ranged in size from 30 to 70 mm and were maintained

[1]This study was conducted in cooperation with U.S. Department of Commerce, NOAA, National Marine Fisheries Service, under PL 88–309, Project No. 2–325–R.

Manuscript received August 28, 1980; accepted September 15, 1980.

in aquaria refrained from attacking live adult grass shrimp (15 to 25 mm in length) introduced into the tank. However, fish over 80 mm actively fed on such shrimp in the aquarium.

In conclusion, it appears that environmental changes play a major role in the distribution of *E. funduli* and probably contributed to its spread to Horn Island.

**ACKNOWLEDGMENTS**

We thank Donald Bump and James Carter for their help in collecting fish, Dr. Richard Heard for examining stomach contents of several fish, Rena Krol for typing the manuscript, and Dr. Robin M. Overstreet for reviewing this paper.

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# Gulf Research Reports

Volume 6 | Issue 4

January 1980


## Vertebral Anomaly in *Fundulus similis*


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DOI: 10.18785/grr.0604.13

*Gulf Research Reports,* Vol. 6, No. 4, 429, 1980.

# VERTEBRAL ANOMALY IN *FUNDULUS SIMILIS*

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*ABSTRACT* On May 11, 1978, a longnose killifish, *Fundulus similis*, exhibiting an extreme lordotic, scoliotic condition was collected on the north shore of Big Lagoon in Escambia County, Florida. The specimen was held for observation in a flow-through seawater aquarium for several weeks prior to being preserved and placed in the Gulf Breeze Environmental Research Laboratory Museum (No. AN-2146).

Vertebral anomalies have been reported in many fishes (Dawson 1964, 1966, 1971; Dawson and Heal 1976); however, I am unaware of any such reports for the longnose killifish *Fundulus similis* (Baird and Girard).

This specimen, standard length 54 mm (Figure 1), was collected on May 11, 1978, by Larry Goodman, James Patrick, Jim Filand, and me in a 6.1 m beach seine on the north shore of Big Lagoon, approximately 1.1 km east of Trout Point, in Escambia County, Florida (salinity = 6 ppt, temperature = 28°C). Radiographs (Figure 1) taken shortly after capture show severe lordosis and scoliosis of the caudal vertebrae with a suggestion of abnormal rotation of the vertebrae on their longitudinal axis. The vertebral count revealed 14 thoracic and 20 caudal vertebrae.

The specimen was maintained with several similar sized longnose killifish in a flow-through seawater aquarium for observation for nine weeks. The extreme lordotic and scoliotic condition appeared to have little effect on the animal's ability to obtain food, maintain itself in the water column, or conduct itself "normally" under aquarium conditions. At the time of collection, and again four weeks after being placed in the aquarium, the specimen displayed male breeding coloration as described by Springer and Woodburn (1960). After nine weeks, the killifish developed fin rot and was preserved to avoid further degradation of tissues. The preserved specimen is now housed in the Gulf Breeze Environmental Research Laboratory Museum (No. AN-2146).

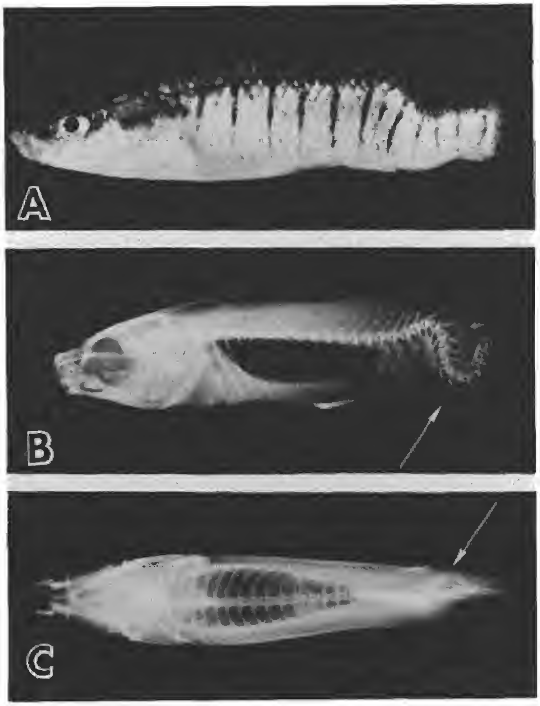


Figure 1. *Fundulus similis* from Escambia County, Florida. (A) Lateral view reveals anomalous morphology. (B) Radiograph reveals the extreme lordotic condition and slight rotation of vertebrae on their central axis. (C) Radiograph shows a lateral curvature (scoliosis) of the posterior caudal vertebrae (arrow).

## ACKNOWLEDGMENTS

I thank Lee Courtney for radiographs, Steve Foss for photographs, and Dr. John Couch for examination of the radiographs.

Manuscript received March 6, 1980; accepted March 17, 1980.

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# Gulf Research Reports

Volume 6 | Issue 4

January 1980


## Activities of the Gulf Coast Research Laboratory During Fiscal Year 1979-80: A Summary Report


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DOI: 10.18785/grr.0604.14





Recommended Citation

Howse, H. D. 1980. Activities of the Gulf Coast Research Laboratory During Fiscal Year 1979-80: A Summary Report. Gulf Research Reports 6 (4): 431-451.
Retrieved from http://aquila.usm.edu/gcr/vol6/iss4/14

*Gulf Research Reports*, Vol. 6, No. 4, 431–451, 1980.

# ACTIVITIES OF THE GULF COAST RESEARCH LABORATORY DURING FISCAL YEAR 1979–80: A SUMMARY REPORT

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## ADMINISTRATION

Progress this year was interrupted temporarily by Hurricane Frederic on September 12, 1979. The eye of the storm made landfall east of the Laboratory; consequently, no tidal surge accompanied the hurricane in the local area, but there was enough high water to destroy the Laboratory's new pier on Davis Bayou. In addition to sustaining numerous downed trees and utility lines, the Laboratory facilities received damage totaling about $80,000.

The greatest impact on the research programs involved the loss of or damage to scientific data, instrumentation, experimental animals and other specimens.

Construction of the Laboratory's oceanographic research vessel resumed following the signing of a contract between the State Building Commission and Bender Shipbuilding and Repair Co., Inc., Mobile, AL. Delivery of the vessel is expected in January 1981. Work on the vessel stopped in 1976, when the original contractor defaulted. The unfinished hull had been moved and stored at Misener Industries, Inc., Tampa, FL.

Because of spiraling costs of construction, the State Building Commission was unable to obtain an acceptable bid for constuction of the proposed new Marine Education Center building on the Biloxi campus. Therefore, the building has been redesigned, and will contain about 32,700 gross square feet. The building will provide demonstration and teaching laboratories, a fisheries information and service center, seafood microbiology lab, offices, an auditorium, and an aquaria display. Bids on this building will be taken early in the next fiscal year.

The annual operational budget consisted of $2,100,000 in State-appropriated funds, $859,178 in sponsored research and other funds, and $25,000 in Library Improvement Funds allocated by the 1979 State Legislature.

In addition, the State Legislature appropriated $175,000 in State matching funds for use by the Mississippi-Alabama Sea Grant Consortium in funding the Mississippi Sea Grant Program.

### *BOAT OPERATIONS*

The boats that provided essential services included the 65-foot R/V GULF RESEARCHER, used in both the Laboratory's research and educational programs; the 38-foot steel trawler HERMES, used principally in the educational program; three diesel-powered cabin workboats; and some half-dozen Boston Whalers and other miscellaneous smaller craft powered by gasoline motors. The larger vessels are operated by six full-time boatmen, three of whom are licensed Masters for vessels of up to 100 gross tons. The Boston Whalers and other miscellaneous smaller boats are operated by scientists and technicians to meet the needs of some Laboratory research projects. A new 100-foot research vessel which is being completed at Bender Shipbuilding and Repair Co., Inc., Mobile, AL, is scheduled for delivery to the Laboratory in FY 1980–81.

During the year ended June 30, 1980, R/V GULF RESEARCHER was at sea for 66 days and 27 nights. The HERMES spent 62 days at sea and the smaller boats made innumerable trips over the same period.

## RESEARCH

### *ANALYTICAL CHEMISTRY SECTION, Dr. Thomas F. Lytle, Head*

***Sediment-Nutrient Interaction Study*** (Funded by Mississippi-Alabama Sea Grant Program [M-ASGP]): Much of the nutrient budget in a coastal estuary is bound in surface sediments. Resuspension of these sediments is known to release some of the nutrients in soluble form, which may or may not pose a danger to the biological community. Because of storms, dredging, and other modes of sediment disturbance prevalent in the Sound, a study was made of sediment-nutrient release and adsorption. Two areas of the Pascagoula River region were studied because of a history of industrial pollution. Sediments from both Bayou Cassotte and the lower Escatawpa River were suspended in site water, and the soluble-nutrient levels were measured. All forms of nitrogen, phosphorus, and silicon showed no increase in water exposed to Bayou Cassotte sediments; whereas dramatic increases were seen with Escatawpa River sediments. Other chemical analyses indicated that the dredging activity in Bayou Cassotte has served to remove most of the leachable material from surface sediments in that area. To substantiate these conclusions, other laboratory experiments are being devised to study the effect of dredging on particulate-bound nutrients.

***Sediment Toxicity Index*** (Funded by M-ASGP and Gulf Coast Research Laboratory [GCRL]): A technique is being devised to provide a toxicity rating of sediments in Mississippi Sound. Several factors are involved in achieving an objective means of evaluating the toxicity of sediments.

Two factors that have been investigated are suspension characteristics and toxicological testing. Areas that have been scrutinized are the Escatawpa River and Bayou Cassotte. It was found in three-phase bioassays provided by the Toxicology Group of GCRL, that sediments from Escatawpa River were more highly toxic to mysid shrimp than those from Bayou Cassotte. In associated studies it was found that sediments from the Escatawpa River exhibited a much higher suspension stability than those from Bayou Cassotte. Suspensions of sediments from both regions were studied as a function of suspended solids versus time. The time for solids to drop to 1/2, 1/4, and 1/8 original value was approximately an order of magnitude greater for Escatawpa River sediments than for Bayou Cassotte sediments. These sedimentation rates bear a significant relationship to the sediment-toxicity potential in a particular region; they are being used in conjunction with toxicological data in evaluating the threat posed by contaminated sediments in Mississippi Sound.

***Phenolic Compounds in Sediments of Mississippi Sound*** (Funded by M-ASGP): Of the various types of pollutants suggested by National Pollutant Discharge Elimination System (NPDES) permits (industrial and residential discharge limits) as being of concern in Mississippi Sound, phenols are one class of compounds which are evident in a great number of effluents. In an examination of sediment cores from the Sound, phenols have been analyzed as indicators of pollutant penetration into the sediment column, and as historical tags of industrial development in the region. Thus far in the Pascagoula River region, evidence points to deposition of phenolic materials to depths exceeding 10 feet at the parts per million level in the river, and undetermined amounts were seen in regions just east of the river mouth. The significance of these findings is being studied by a careful analysis of the phenols present to specify type and source. Relatively high levels of phenols have been seen at depths in the sediment column that, by other analytical approaches, predate industrial input. A natural source of some phenols is probable.

***Shrimp-Waste Fertilizer Feasibility Study*** (Funded by Southern Mississippi Planning and Development District): Samples of shrimp-processing wastes were analyzed in an effort to determine the feasibility of using them as fertilizer in a pilot testing program. Wastes were analyzed by standard fertilizer analytical techniques for organic nitrogen, nitrate, nitrite, ammonia, phosphate, potassium, moisture, sulfur, ash content, calcium, chloride, and several trace elements. Results demonstrated no present threat to the environment from trace metal levels or from soluble salt content. Major nutrients were not as high as expected, but were sufficient to pursue further this use of seafood wastes.

***Polynuclear Aromatic Hydrocarbon-Rapid Scanning*** (Funded by M-ASGP and GCRL): The polynuclear aromatic hydrocarbons (PNAs), residues of petroleum pollution, are of great concern because of their carcinogenic properties. Many pollution studies calling for PNA analysis are handicapped by the time-consuming and very costly measurement techniques usually assumed to be state of the art. Fluorescence scanning (emission, total excitation, and synchronous) is another technique that allows characterization of ring-size distribution of aromatics. The technique has been applied and developed for sediment samples in Mississippi Sound. On the samples analyzed thus far, the technique showed great promise for the routine monitoring of PNAs in sediments, and perhaps in other media as well.

***Heavy Metals in St. Louis Bay*** (Funded by E. I. duPont de Nemours & Company, Inc. [Du Pont] and GCRL): The introduction of big industry near St. Louis Bay in 1978, prompted a study of baseline heavy metal levels in bay waters, sediments, and organisms. Surface-water samples were collected every other month during 1978 from eight locations, and a bottom-water sample was collected at a site positioned to monitor tidal input of heavy metals. Water analysis was included to provide "typical" values of instantaneous heavy metal levels in St. Louis Bay. Surface sediment samples were collected twice at 6-month intervals from 15 locations. Sediments which depict an integrated history of metal deposition were used as long-term measures of metal accumulation. As indicators of biological accumulation and magnification, oysters and clams also were collected and analyzed. Several fish-collection trips were made so as to include a greater variety of organisms; however, insufficient numbers were obtained of most species to give statistically meaningful results. Therefore, only *Rangia cuneata* and *Crassostrea virginica* were used in the analytical scheme. Metals analyzed were: arsenic, antimony, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, strontium, titanium, vanadium, zinc, and iron.

Analysis of all samples was completed in November 1979, and a final report of the results has been submitted. These data were discussed from the standpoint of: (1) seasonal variation of metal levels, (2) riverine versus tidal input, (3) soluble and particulate fractionation of heavy metals in the water column, (4) comparisons with previous studies in St. Louis Bay and other geographically similar areas, (5) heavy metal depositional areas in St. Louis Bay, (6) relationship of particulate to sediment metal, and (7) correlation of sediment heavy metals with organic carbon and grain size distribution.

***BOTANY SECTION, Dr. Lionel N. Eleuterius, Head***

***Salt Marsh Vegetational Studies*** (Funded by GCRL): Quantitative information was accumulated on the relationship of marsh acreage versus open water in Davis Bay, a very productive estuarine system. In addition, the total area drained and amount of rainfall will be determined in this study of an entire estuarine ecosystem from the plant ecology viewpoint. A detailed vegetative map is being prepared as well as a map of the standing crop of all marshes

surrounding Davis Bay. This work has been expanded to include salt marshes on Deer Island. Vegetational structure of other Mississippi salt marshes is being determined also. These studies will reveal the vegetational and ecological attributes of very productive estuarine systems which may have far-reaching consequences.

*Ecological Studies on Seagrasses* (Funded by GCRL): Plans were made in late 1979 and early 1980 to begin work on seagrasses in FY 1980–81. A proposal has been written for research on this subject.

*Populational Studies on Salt Marsh Species* (Funded by GCRL): This ongoing research was concentrated on the salt marsh rush *Juncus roemerianus*. Considerable population information has been gathered on the species and a portion of it is now in manuscript form. The ultimate goal is to document the distribution and the vegetative growth pattern of the major salt marsh species inhabiting tidal marshes in Mississippi. Such populational studies are of considerable importance in relation to ecological work since ecotypes, single sexes, may dominate or compose large tracts of tidal marsh. Taxonomic work was initiated as part of this study.

*Ecological Studies on the Plant Life of Salt Marshes* (Funded by GCRL): This work involves synecological studies where more than one species compose the vegetation. Included is consideration of the hydraulic aspects of flooding various salt marsh zones, done in cooperation with the Physical Oceanography Section. Grand Bayou, a high-salinity marsh dominated by *Juncus roemerianus* on Deer Island, Mississippi, has been selected for this portion of the study. Tidal inundation and discharge rates can easily be established because of the small, contained ecosystem represented in Grand Bayou. A paper was published on tidal inundation and exposure. Quantitative data on plant productivity and the nutritive discharge of detritus and other water-quality parameters will be assessed on the discharge and on the rising tide. The nutrients of Grand Bayou salt marshes in relation to flood and ebb tides, and the flux of soil-water salinity have been determined and manuscripts are in preparation for publication.

Studies have been initiated of other ecological aspects of tidal marshes. Biotic effects are also considered. Flowering phenology has been determined and a paper is in preparation. Two graduate students received degrees; one did research on the response of the snail *Littorina* to the manipulation of salt marsh vegetation, and the other did research on the response of the vegetation to nutrient enrichment.

*Autecological Studies on Vascular Plants of Mississippi Salt Marshes* (Funded by GCRL): This is essentially an extension of populational studies, in that ecological parameters such as soil nutrients, soil-water salinity, elevation, and other chemical and physical aspects of habitats (i.e., soil texture, evaporation), and the life history of the plant including germination are considered.

*An Illustrated Guide and Key to Salt Marsh Plants* (Funded by M-ASGP and GCRL): The purpose of this work is to prepare an illustrated guide and key to the salt marsh plants of Mississippi. It entails 200 line drawings and scientific descriptions of local species of vascular plants. Additional funds were received to expand and extend this project.

*St. Louis Bay–Botanical Survey and Plant Ecology of Salt Marshes and Submerged Meadows* (Funded by Du Pont): This work was completed in FY 1979 and the final report was submitted in FY 1980. Vegetational mapping and community composition of salt marshes and submerged grass beds were documented. Standing crop, annual production, and chemical characterization of indicator plants and associated soils were determined as part of a baseline environmental study.

*Herbarium Collection of the Coastal, Estuarine, and Marine Flora* (Funded by GCRL): The herbarium presently houses about 20,000 specimens of plants and includes spermatophytes, algae, and fungi. Most of the collections have been made locally since 1970; they probably compose the most thorough collection of plants found in the northern Gulf of Mexico. Most of the plants have been identified but only a few have been mounted on herbarium sheets. The herbarium is presently being organized and specimens cataloged systematically. Duplicate specimens are exchanged with herbaria throughout the United States, England, Europe, Australia, and South America for collections of their coastal, marine, and estuarine plant specimens. The herbarium serves as a teaching and research collection.

*Tropic versus CONUS Military Materials and Equipment Evaluation Test* (Funded by U.S. Army): This experiment was initiated in the spring of 1979 as part of a nationwide military program to determine the effect of environmental factors on various military materials and equipment. This work was completed in 1980.

*Studies of Plant Colonization on Dredge Spoil* (Funded by GCRL): A considerable amount of information has been compiled over several years on plant colonization of dredged material. In addition, some information on plant succession has been gathered. A more intense field effort has been initiated.

*Productivity and Decomposition Studies on Salt Marsh Plants* (Funded by GCRL): Several studies were completed on this aspect of salt marsh research, including estimates of standing crop, and two regeneration studies. Assessment of decomposition was determined using nylon bags and new methods were developed by the section staff. Manuscripts have been prepared on these projects and hopefully will be published during the coming year.

#### *ECOLOGY SECTION, Dr. Robert A. Woodmansee, Head*

*Phytoplankton Productivity in St. Louis Bay* (Funded by GCRL): Phytoplankton productivity is a fundamental community process of primary significance to the aquatic food chain. It is affected by a number of naturally occurring variables and is sensitive to a variety of

unnatural environmental perturbations. The photosynthetic rate of phytoplankton is being measured at six locations in St. Louis Bay by both the dissolved oxygen and radioactive carbon techniques, and is being related to light intensity, temperature, nutrients, chlorophyll, community composition, and grazing pressure.

***Environmental Baseline Survey of St. Louis Bay: Benthic Study*** (Funded by GCRL): Field collections for this baseline study were completed in November 1979. Approximately 50% of the collections from the second year have been processed and stored at the Laboratory. Results of this continued study will be used in conjunction with data from the first year to investigate seasonal cycles and year-to-year changes in the benthic infauna of St. Louis Bay.

***Population Study of the Amphipod Cerapus benthophilus in Davis Bayou*** (Funded by GCRL): The possibility of amphipod tubes as a potential high-protein food source for juvenile and adult brown shrimp has been discussed in the literature. *Cerapus benthophilus* inhabits muddy silt bottoms subject to current flow, where it constructs conspicuous mats of interwoven tubes. Thus, the extensive coverage of *C. benthophilus* in coastal marsh systems of the northern Gulf of Mexico may represent an unrealized food source. The purpose of this study is to describe the benthic community associated with these mats, and to determine seasonal fluctuations in abundance of *C. benthophilus* and other associated fauna.

***Mississippi Sound and Adjacent Areas Study–Biological Committee*** (Funded by M-ASGP): As a result of numerous existing and proposed dredging activities in Mississippi Sound and adjacent areas, the Mobile District Corps of Engineers has initiated a study to investigate current dredging and dredged material disposal practices. The study will consider the possible development of a regional dredging management strategy, new dredging equipment, and the environmental quality of the study area. The Biological Committee, composed of five GCRL senior staff members, is responsible for aiding in the development of scopes of work for collection of biological data related to the study, for identifying specific techniques and methodologies to obtain and analyze such data, and for using the data in formulating plans and measuring impacts.

***ENVIRONMENTAL CHEMISTRY SECTION, Dr. Julia S. Lytle, Head***

***Broad Spectrum Sediment Contaminant Survey in Mississippi Sound*** (Funded by M-ASGP and U.S. Environmental Protection Agency [EPA]): To understand the fate of pollution one must know what types of compounds are present to monitor and study. Discharge permits and pollution incidents in Mississippi Sound indicate that organic-type pollutants are most prevalent. However, previous effluent guidelines and possible abuses of regulations probably have resulted in quite an aggregate of pollution components in the Sound. To study the fate and effects of pollutants, representatives of all important classes of suspect compounds must be evaluated for inclusion in an analytical scheme. A broad spectrum approach is being taken to determine both major and minor components present in the sediments. There is no predetermined list of compounds. Only recently has the practical and economical pursuit of this goal been made feasible, by the development of computerized gas chromatography-mass spectrometry systems. An agreement continued in effect with the EPA laboratory at the National Space Technology Laboratories (NSTL) in Bay St. Louis, to exchange data for the use of such a system. This agreement, besides providing GCRL with expanded analytical capability, permits the EPA access to a vastly better sampling and analysis base in Mississippi Sound.

***Characterization of Olefinic Hydrocarbons in Carbonate and Clay-Silt Sediments*** (Funded by Carnegie Institute, Geophysical Laboratory, Washington, D.C. and GCRL): Residues of organic matter trapped in sediments serve as fingerprints of the biological environments above them. Complex mixtures of compounds are isolated from the sediment and reflect the source of material being deposited (either man-made pollutants or natural deposits from plants and animals). In past studies, some sediments analyzed from the Gulf of Mexico have indicated extremely high concentrations of olefinic hydrocarbons. Some possible sources have been identified, but the characterization of these olefins, other than the simple straight-chain alkenes, has not yet been done. A separation and characterization study on these branched and cyclic olefins is in progress. Processes may be operative in marine sediments which convert olefinic isomers to other configurations thermodynamically more stable; the study will improve our knowledge and comprehension of those post-depositional processes. One particular olefinic compound(s) found in the Gulf only in carbonate sediments has been isolated and documented by publication. Other research groups also report this compound(s), but they also have been unsuccessful thus far in establishing the source and characterization. Because it represents the dominant hydrocarbon of marine carbonate sediments, it is important to clarify its complete identification and role in deposition of carbonaceous sediments.

***Studies of Chemical Constituents of Primitive Plants*** (Funded by GCRL): Chemotaxonomic and geochemical studies are continuing on primitive plants. Studies have been completed on ferns, mosses, fungi and lichens. Limited numbers of species of lilies, rushes, sedges and grasses have been analyzed, but additional species collections and analyses must be made to complete the study. There are two purposes of the study. One purpose is to investigate the distribution of biosynthetically related compounds, hydrocarbons, and fatty acids, relate them to a series of ancient plants, and determine what chemical changes took place in the evolution of plants. The other purpose is to establish hydrocarbon and fatty acid distribution patterns which can help in identifying natural source materials and their environments, and in distinguishing them from pollutant sources.

***Relationships of Particulate and Dissolved Organic Matter in Brackish Waters*** (Funded by M-ASGP and GCRL): It is important to understand the origin and fate of organic matter in Mississippi estuaries. Dissolved organic carbon (DOC) possibly originates from a different source than does particulate organic carbon (POC). Water samples from the Wolf and Jourdan rivers, and St. Louis Bay are being collected monthly and analyzed for both DOC and POC. In the estuary, organic detritus often represents a major component in the food chain. Detritus can be imported from the Sound and the Gulf or exported from riverine and marsh sources. Evaluation of the sources of DOC and POC will provide insight into import and export from the estuaries, as well as provide a better understanding of the carbon cycle in estuarine waters.

***Sediment Suspension Impact Studies*** (Funded by GCRL and M-ASGP): When sediments are suspended by various means (dredging, boating, wind and water scouring), the associated pollutants can be redissolved, oxygen depletion in the water column occurs, and other chemical changes take place. Surface sediments from the Pascagoula River area, including the Escatawpa River and Bayou Cassotte, are being analyzed in experiments devised to duplicate incidents of sediment disturbance. The degree to which toxic materials are adsorbed or released, and the sedimentation rates under varying physical conditions (pH, temperature, salinity) are being measured to determine the impact of contaminated sediment resuspension in various locales of Mississippi Sound. The information gained will be used in evolving guidelines for a coastal zone management policy to be developed by the state Bureau of Marine Resources (BMR).

***Pascagoula River Sediment Deposition Studies*** (Funded by M-ASGP and GCRL): Pascagoula River water flows into Mississippi Sound, carrying with it large amounts of suspended sediments. Major flow is to the west and out through Dog Keys Pass. Riverine sediments with associated pollutants can thus migrate across the Sound and into the Gulf. This study was designed to understand better the transport of pollutants and to locate pollutant sinks. Sediment and water samples have been collected along a transect from the mouth of the Pascagoula River to the western end of Horn Island, which is along the path of river flow in the Sound. Aliphatic and aromatic hydrocarbons are being analyzed by fluorescence spectrophotometry and gas chromatography. Riverine sediment transport can be followed because riverine sediments primarily contain terrestrial organic input whose hydrocarbon distributions are characteristic and are readily distinguished from marine organic inputs to sediments. Other chemical parameters unique to Pascagoula River waters are also being investigated as tracers. Transport of Biloxi riverine sediments will be included in this pollution deposition study.

***FISHERIES MANAGEMENT SECTION,*** *Mr. William J. Demoran, Head*

*Oyster Resource Flood Damage* (Funded by GCRL): Investigators monitored the effects of spring flooding on the oyster reefs in state waters again this year. Some additional mortality was noted on certain reefs, particularly in eastern Mississippi Sound off Pascagoula. However, it appeared that sufficient spawning stocks remain on all reefs to repopulate the damaged areas.

*Oyster Reef Rehabilitation* (Funded by GCRL): Personnel assisted the BMR in planning and supervising its annual oyster reef rehabilitation project. During the project, 21,000 cubic yards of clam shells were spread on oyster reefs in the three coastal counties. Old reefs were enlarged in some areas and some new reefs were constructed. The new reefs should produce oysters for several years without having to be refurbished.

*Seed Oyster Location* (Funded by GCRL): The section aided local oyster growers in locating seed oysters for relaying on private leases prior to the 1979–80 oyster season.

***National Marine Fisheries Service (NMFS), Marine Recreational Fish and Shrimp Survey*** (Funded by NMFS through Human Science Research, Inc.): Section personnel coordinated a survey of the Mississippi coastal area, which included hiring and training interviewers, assigning survey dates, and processing interview forms and invoices.

***FISHERIES RESEARCH AND DEVELOPMENT SECTION,***
*Dr. Thomas McIlwain, Head*

***ANADROMOUS FISHES:***

***Striped Bass Restoration Program—Mississippi Gulf Coast*** (Funded by NMFS, U.S. Fish and Wildlife Service [USF&WS] and GCRL): The first segment of the project dealing with the rearing and stocking of striped bass was begun in September 1979. The objectives of the program were to establish, by rearing and stocking, a striped bass population in Biloxi Bay; to stock sea-run striped bass and determine their success; and to establish a source of fry from Mississippi brood fish.

Approximately 389,400 striped bass of South Carolina origin were stocked into Biloxi Bay. The USF&WS provided 198,000 fingerlings from the hatchery at Meridian, MS, and the remaining 191,400 were obtained as fry and reared at GCRL. The fish released by GCRL represented 31% of the total number of live fish received from South Carolina.

An additional 222,800 sea-run striped bass fingerlings were reared from fry obtained from the state of Virginia. The fingerlings released represented 50% of the live fish received from Virginia. These fish, along with 168,000 fingerlings provided by the USF&WS from the Carbon Hill, AL, hatchery were stocked into St. Louis Bay.

A sampling program is in progress to monitor natural reproduction. The program also consists of sampling for juvenile striped bass, and sampling the striper population resulting from previous stocking programs.

***Description and Comparison of the Eggs, Larvae, and Young of the Yellow Bass, Morone mississippiensis, with White Perch, and White Bass*** (Funded by GCRL): Adult

yellow bass were collected from local streams and spawned in the laboratory. The resulting eggs, larvae, and young are being described and compared to the eggs, larvae, and young of striped bass and white bass. Collections of white bass and yellow bass have been acquired for comparative purposes.

*Food Habits and Feeding Selectivity of Larval Striped Bass under Intensive Culture Conditions* (Funded by GCRL): This is the third year of a three-year study. The study was moved from the laboratory into a production unit. Several types of live foods and prepared dry diets were tested as food for larval striped bass reared under intensive culture conditions. The best growth was achieved by starting the larval fish on live brine shrimp and then switching them to a dry diet fed daily by an automatic feeder. The highest survival was achieved employing a combination diet of wild zooplankton and live brine shrimp nauplii.

*COMMERCIAL AND RECREATIONAL FISHES:*

*Contributions to the Life History of the Southern Kingfish, Menticirrhus americanus (Linnaeus) in Mississippi* (Funded by BMR): This study was designed to collate all locally available life history data on the southern kingfish. After these data were analyzed, a sampling and analysis program was designed and implemented to fill identified data gaps, particularly emphasizing spawning time and fecundity. Offshore collections are being carried out in cooperation with the NMFS Laboratory in Pascagoula, MS.

*Fishery Monitoring and Assessment* (Funded by NMFS and GCRL): Monthly samples were collected and processed. Verified data and selected analytical programs were stored in the Laboratory computer. Selected analytical programs were used to write and publish reports on the relative abundance, size, growth, and distribution of harvestable species each month.

Cooperative efforts were continued to expand the fishery data base for use in achieving optimum production from Mississippi fishery resources through effective management planning and implementation. Information provided to the Mississippi Department of Wildlife Conservation, Bureau of Marine Resources, National Marine Fisheries Service, Gulf States Marine Fisheries Commission, Gulf of Mexico Fisheries Management Council (GMFMC), fishermen, the fishing industry, and other state and federal agencies contributed to a progressively improving scientific basis for Mississippi marine fishery management.

Special shrimp sampling provided the BMR with a scientific basis for the opening of shrimp fishing seasons. The Bureau opened the season on June 23, 1980, after examining predicted dates and considering economic and social factors. Monitoring of the shrimp resources was continued after the season opened. With the possible exception of the 1980 brown shrimp crop, all resources monitored in this project appeared to be in good condition.

In April 1980, oysters were added to the assessment and monitoring project. Effects of spring floods were monitored and assistance was provided to the BMR in efforts to rehabilitate flood devastated reefs. Results indicate a good set of oyster spat on newly planted shell and some viable oysters off the Telegraph Reef area. Eight reefs across Mississippi are surveyed monthly.

Specimens collected in this project were provided to students and other agencies on request. The by-catch of the special shrimp sampling program and monitoring samples collected since the fishing season opened are being used as the basis for a master's thesis.

*Fisheries Planning* (Funded by GCRL, NMFS, BMR and GMFMC): Active participation in fishery management planning activities of all concerned agencies in the Gulf of Mexico and several professional societies provided for effective input of Mississippi's interest in all Gulf fishery management planning activities. Fisheries personnel served in important positions including chairmanship and membership in key committees.

*Environmental Baseline Survey of St. Louis Bay, Nektonic Macrofauna* (Funded by GCRL): This project was a continuation of a study initially funded by a private industry through June 1979. The Laboratory supported sampling through September 1979. This sampling effort provided two full years of data and strengthened the baseline data bases.

*ICHTHYOPLANKTON:*

*The Role of Mississippi Sound in Recruitment to Sport and Commercial Fish Stocks* (Funded by M-ASGP and GCRL): Since November 1979, 22 stations covering the entire east-west and north-south extent of Mississippi Sound (including three island passes and three offshore sites) have been sampled for fish larvae with an opening/closing meter net. Overall larval fish abundance progressively increased from winter through early summer with the highest abundance and greatest number of taxa occurring at the island passes and offshore stations. In late spring and early summer, larval abundances rose dramatically within the Sound, primarily due to anchovy spawning. Menhaden, spot, and Atlantic croaker dominated the samples in winter and early spring; in late spring and early summer anchovies were most abundant.

When completed this study will provide a comprehensive overview of the areal and within-water-column distribution of larval fishes within Mississippi Sound. With these data and data on the hydrographic and chemical properties of Sound waters (provided by other GCRL researchers) an effort will be made to describe the possible mechanisms of larval transport into and maintenance within the region. Seasonal occurrence, abundance, and length frequency data will yield insight into the importance of Mississippi Sound to the survival of early life stages of local fishes, especially those of commercial significance in the northern Gulf.

*Cooperative Billfish Study* (Funded by GCRL in cooperation with NMFS): Although billfishes are an important

recreational and commercial resource in the Gulf region, larval stages of three species—blue marlin, white marlin, and sailfish—cannot be readily separated from each other. Larvae could provide a tool for resource assessment purposes, but only if identification can be accomplished with certainty. Work is continuing to resolve larval identification problems within this group.

*Assessment of the Utilization of Mississippi Biloxi Bay Area for Sciaenid Spawning and Early Life History* (Funded by BMR and GCRL): Monthly surface and bottom meter net samples were taken at three stations in Back Bay and at one station in Biloxi Bay, to provide data on the occurrence and abundance of early larval stages of sciaenid fishes, and information on the incidence of spawning in those areas. Sampling was initiated in April and by July 1980, 24 samples had been collected and the fish identified, yielding larvae and juveniles of five species of sciaenids, *Bairdiella chrysura, Cynoscion arenarius, C. nebulosus, Leiostomus xanthurus,* and *Menticirrhus americanus.* During the months sampled, no major concentrations of early larvae, indicative of local spawning, were observed.

*Larval Fish Collection* (Funded by GCRL): Progress was made toward establishing a good working reference collection of identified larval fishes from the Gulf of Mexico region. Identified specimens now number 11,845 representing 52 families. Specimens have been provided as gifts or on loan from Texas A&M University, University of West Florida, Rutgers University, and GCRL. Loans have been made to the Virginia Institute of Marine Science. Personnel from the University of South Alabama, University of Southern Mississippi, Louisiana State University, and Humboldt State University visited and used the collection. The collection is intended as a reference source for systematic and ecological studies on the early life history of fish, as well as a teaching tool for graduate students interested in early life history research.

*Taxonomy of Larval Carangid Fishes* (Funded by GCRL): Taxonomic studies have begun on larvae of carangid fishes of the northern Gulf of Mexico. The jacks and pompanos (family Carangidae) are represented by 25 species and 14 genera in the northern Gulf. Carangids are an abundant and important group of fishes in the northern Gulf and frequently are taken as larvae in plankton samples.

Although other workers have published descriptions for about two thirds of the species, many descriptions are incomplete, some are inaccurate, and none can be relied upon to distinguish prefin formation larvae.

As a result of early studies, a paper was presented at the Annual Meeting of the American Society of Ichthyologists and Herpetologists held at Texas Christian University, June 1980, which outlined the state of the art in larval carangid taxonomy among northern Gulf species, and pointed out specific problems encountered.

*Identification of Goby Larvae* (Funded by GCRL): The gobies, sleepers, and wormfishes (Gobiidae, Eleotridae, and Microdesmidae) are a group of fishes with about 16 species occurring in the Mississippi Sound estuary. Adults and juveniles are abundant in this area and at times the larvae are abundant in plankton. To date most studies have dealt with adult and juvenile forms only. Little information is available on early life history and larval development of species in these families.

Currently it is possible to identify the larvae of three species, *Dormitator maculatus, Gobiosoma bosci,* and *Gobionellus boleosoma.* Within laboratory collections there are numerous other types which have not been identified at this time. Work underway involved the analysis of preserved material and rearing experiments to aid in the identification of the remaining types.

*Age and Growth of Sciaenid Larvae using Daily Increments on Otoliths.* (Funded by NMFS): Growth of zero-age fish in the sea has not been well documented, principally because a method for determining the age of larvae and juveniles has not been available until recently. The discovery of daily growth increments on otoliths has made possible the precise determination of age, in days, of larval and juvenile fishes.

Otolith growth increments will be used to determine rates and patterns of early growth of the Atlantic croaker, *Micropogonias undulatus;* spot, *Leiostomus xanthurus;* and sand seatrout, *Cynoscion arenarius,* within Mississippi Sound. Results will be compared with previous estimates of early sciaenid growth in the field which were based on less precise methods, such as mark-and-recapture, and length-frequency analyses.

This was only a preliminary investigation into the growth of larval and juvenile sciaenid fishes. It might lead to more comprehensive studies into factors affecting growth such as ontogenetic changes, and temporal and spatial parameters.

*Identification of Small Larvae of King and Spanish Mackerel* (Funded by GCRL): Both king and Spanish mackerel are important resources in the Gulf of Mexico. Although studies have been published on the early life histories of these two species, small larvae (< 3 mm in length) have not been adequately described. Based on collections taken off Texas, additional characters have been found to aid in the separation and identification of small larvae of the two species. This work was conducted in cooperation with personnel of Texas A&M University. Results are being prepared for publication.

*Patterns of Larval Fish Occurrences in Surface Waters of the Northern Gulf of Mexico* (Funded by GCRL): The Gulf of Mexico is perhaps one of the least known areas around North America in terms of ichthyoplankton, particularly the northern Gulf. Yet this is one of the most diverse areas ecologically and faunistically. Within the "Fertile Fisheries Crescent" there are no published comprehensive accounts (species, time, and space) of ichthyoplankton in offshore waters.

This study, based on a series of monthly (January 1967 to May 1969) nekton collections taken at six stations in

the northern Gulf of Mexico, has yielded some of the first information on spatial and temporal patterns of larval fish occurrences in surface waters in this region. Numerical dominants included menhaden, spot, and pinfish. Spatially, species had abundance centers located either inshore, mid-shelf, or offshore. Temporally, species were classified either as winter or summer types.

Preliminary findings were presented at the 60th Annual Meeting of the American Society of Ichthyologists and Herpetologists in June 1980. Results are being prepared for publication. Aspects to be discussed in the publication include clupeoid dominance, differing early life history strategies of two co-spawning sciaenids (spot and croaker), the strong two-season trend of larval fish occurrences in relation to current circulation patterns and estuarine dependence, and the peak of anchovy abundance mid-shelf relative to anchovy dominance in the surf zone of a barrier island.

*GEOLOGY SECTION, Dr. Ervin G. Otvos, Head*

*Offshore Barrier Island Study* (Funded by GCRL): The purpose of the study was to reconstruct the geological history of the barrier islands, including formation conditions and present evolutionary trends. Beach samples were collected during the year from Ship, Horn and Sand islands, and were analyzed. Drilled core samples from previous years were analyzed with respect to microfossil and granulometric content. A cooperative effort on the Pleistocene-Holocene ostracode biostratigraphy in the Mississippi Sound-barrier island area was undertaken with Dr. Paul Krutak, of the University of Nebraska. The accumulated findings are being organized for presentation at professional meetings, and for publication. One paper was published as a chapter in a volume entitled *Barrier Islands* (Academic Press, 1979). Two publications by Otvos from the Conference on Research in the National Parks, November 1979, also dealt with the subject.

*Santa Rosa Island and Sound* (Funded by National Park Service [NPS] and GCRL): Study of the island, its lagoon and adjacent bays continued with granulometric and micropaleontological analyses of earlier drilled core-sample material. Four new coreholes were drilled on the island and one on the mainland to afford complete coverage of the subject area. Results are being prepared for publication. A pamphlet on Santa Rosa Island and the Mississippi-Alabama barrier islands is being prepared in cooperation with NPS scientific personnel for use by visitors to Gulf Islands National Seashore.

*Photogeological Study of Barrier Islands* (Funded by M-ASGP and GCRL): The ongoing development of minor islands has been studied by periodic photographic surveys since 1977. More detailed studies during this year included monthly plane flights over the Mobile Bay ebb-tidal delta area, Dauphin and Horn islands. Recently, the Chandeleur Islands, Louisiana, also were surveyed. These surveys provided monitoring of island restoration (affecting the recreational, fishing and shipping industry) following the devastation by Hurricane Frederic in September 1979. This project included detailed (aerial photo and field) studies of the youngest barrier island along the Mississippi coast ("Horseshoe Island," which was "born" in late September 1979), and the evolution of Sand and Dauphin islands which have been severely overwashed.

*Geology of the Mississippi-Alabama Mainland Coast* (Funded by GCRL): This ongoing project studied the Pleistocene and Holocene stratigraphy, and the influence of tectonic structures on coastal geomorphology. Sample material from eight important coreholes, drilled in Harrison and Jackson counties, were donated by three foundation engineering firms. Granulometric and micropaleontological sample analyses are in progress. One paper was prepared for publication.

*Graveline Bayou (Jackson County, Mississippi) Sediment Granulometry* (Funded by GCRL): Samples were analyzed for the Microbiology Section to aid virological studies in sediments.

*Pollutant Transport in Mississippi Sound Sediment Granulometry* (Funded by M-ASGP): Numerous drill-core samples were analyzed for the Environmental and Analytical Chemistry sections.

*Pleistocene Geology in Southeastern Louisiana* (Funded by GCRL): Field and laboratory work were performed on Tunica Hills creek deposits. This work is significant in evaluating the use of radiocarbon absolute age techniques in proven Pleistocene sediment units.

*St. Louis Bay* (Funded by GCRL): Monthly sediment samples were analyzed in the 1979 continuation of the environmental baseline survey of the bay.

*Apalachicola Bay Area Barrier Island Investigations* (Funded by GCRL): Drill material from 14 coreholes in lagoonal, mainland, and island areas were loaned by Florida State University for analysis. Additionally, two coreholes from St. George Island were donated by a foundation engineering firm. Comparative studies of the Apalachicola Bay and Mississippi coast barrier islands are aimed at establishing the existence of an important barrier-island evolution process.

*MICROBIOLOGY SECTION, Dr. David W. Cook, Head*

*An Assessment for the Conversion of Seafood Processing Wastes into an Environmentally Acceptable Fire Ant Control Product* (Funded by BMR): Studies were conducted to determine the feasibility of utilizing naturally occurring soil microorganisms (primarily actinomyces species) to convert processed shrimp shells into metabolic products which might be toxic to the imported fire ant. Procedures were developed for the purification of chitin from shrimp shells; isolation of actinomyces from soil and marine sediments; growing actinomycete isolated on processed shrimp shells; extraction of metabolic products resultant from these incubations; and

assessment of metabolite toxicity to the imported fire ant. Toxicity evaluations were performed at the Imported Fire Ant Laboratory, Gulfport, MS. Seven different actinomyces cultures were evaluated using a variety of culture techniques and solvent extractants. To date, no conclusive evidence of metabolite toxicity to the imported fire ant has been ascertained.

*Effluent Toxicity Evaluation: First Chemical Corporation* (Funded by First Chemical Corporation [FCC]): The level of toxicity of the final discharge effluent from FCC, Pascagoula, MS, was determined using sheepshead minnow (*Cyprinodon variegatus*), and possum shrimp (*Mysidopsis almyra*) under standard, acute, flow-through bioassay conditions. Effluent was collected from FCC in April, August and December 1979, and in February and March 1980, and returned to GCRL for testing. Effluent toxicity to sheepshead minnows and mysid shrimp ranged from 100 to 25%, and 75 to 10% (100% represents undiluted discharge effluent), respectively. In all cases, effluent toxicity was found to be in excess of allowable limits for at least one test animal. Test animals utilized in these bioassay evaluations were collected, reared, and maintained under the supervision of Dr. Adrian R. Lawler, Parasitology Section, GCRL.

*Pollutant Transport in the Mississippi Sound* (Funded by M-ASGP and GCRL): In connection with the project directed by Drs. Thomas and Julia Lytle, Analytical and Environmental Chemistry sections, respectively, personnel connected with the Toxicology Program at GCRL are presently conducting three-phase bioassay evaluations on sediments collected from rivers tributary to Mississippi Sound. The three-phase tests consist of evaluating the toxicity of the liquid, suspended particle, and solid phase of each sediment sampled. Test animals utilized in these bioassay evaluations were collected, reared, and maintained by the Parasitology Section.

*Bioconcentration Test: Inter-Laboratory Comparison using the Eastern Oyster* (Funded by EPA); In conjunction with four other laboratories, GCRL is currently conducting bioaccumulation evaluations using selected concentrations of DDE, trichlorobenzene, and pentachlorophenol under standard, flow-through conditions. The eastern oyster (*Crassostrea virginica*) is the test animal in all cases. The Oyster Biology Section has been instrumental in the collection and maintenance of test oysters. Testing consists of an uptake phase in which one set of oysters is exposed to a single concentration of each toxicant until steady state is reached. At that point, toxicant delivery is terminated, and the oysters are allowed to depurate, ideally until 90% of the accumulated test material is voided. Oysters and water are periodically sampled during both uptake and depuration, residual test material is quantitated by gas chromatographic methods, and respective bioconcentration factors calculated.

The DDE, trichlorobenzene, and pentachlorophenol portions of these investigations were completed, and respective bioconcentration factors generated were 133, 242, and 475.

*Development of Fate/Toxicity Screening Tests* (Funded by Battelle Memorial Institute, Columbus, Ohio, Subcontract No. T-6423(7197)-037, Prime Contract No. 68-01-5043, EPA): This project was a cooperative effort between the EPA-Gulf Breeze (Florida), and the Gulf Coast Research Laboratory to determine the effect of sediment, water, and sediment and water together on the adsorption, hydrolysis, and degradation of selected toxic materials. Partition coefficients for each test material were determined, and toxicity evaluations were developed to ascertain whether or not the disappearance of test compound results in a concomitant decrease in toxicity.

This year, dursban and bolero were processed through the screening process. Methyl parathion was included as a reference compound in each screening evaluation. Considerable effort has been expended in developing a valid toxicity test for the water and sediment fractions produced in the screening portion of this investigation. *Mysidopsis bahia* and a *Gammarus* species are the respective test animals for toxicity evaluations of water and sediment. These animals are provided by the Parasitology Section.

Data generated thus far indicate that dursban dissipates quite rapidly from both water and sediment, adsorbs readily to particulate matter, and is not substantially affected by biological activity. Sediment and water toxicity appear to decrease with time, but the rate of toxicity abatement seems substantially less than that of disappearance of parent compound. Bolero appears significantly affected by biological activity in that disappearance of parent compound in both sediment and water systems is considerably more rapid under septic conditions as compared to sterile conditions. Bolero tends to adsorb less to particulate matter than does dursban, but, like dursban, decreasing bolero toxicity with decreasing recovery of added parent compound has not been demonstrated conclusively.

*Steam Unit to Aid in Oyster Shucking. Part II. Microbial and Organoleptic Tests of Oysters Exposed to Steam* (Funded by BMR): A steam tunnel was designed for use in oyster shucking plants to relax the adductor muscle of oysters and thus facilitate opening. The effect which heat had on organoleptic acceptability, free liquid content, and spoilage rate of oysters was evaluated. A mild heat treatment in which oysters were exposed to a temperature of approximately 60°C and during which the internal temperature was elevated to 40°C did not significantly alter any of the evaluation characteristics. Oysters subjected to higher temperatures scored lower in organoleptic tests but the free liquid content and spoilage rate appeared unaltered. High temperatures accelerated the glycogen bleeding rate, resulting in cloudy oyster liquor which the test panel determined to be undesirable.

*Viral Evaluation of Prohibited Oyster Growing Waters* (Funded by M-ASGP and GCRL): This joint project with the University of Southern Mississippi is designed to assess

the relationship between numbers of pollution-indicator bacteria in the water and the level of viruses found in oysters. GCRL is responsible for water- and oyster-sample collections and bacteriological analysis. Data produced will be available to state and federal regulatory agencies for use in assessing present-day water quality standards.

*Enteroviruses in Prohibited Oysters and Marine Sediments* (Funded by M-ASGP and GCRL): Oyster and sediment samples were collected from Graveline Bayou and adjacent areas, and analyzed for fecal coliform bacteria and enteroviruses. These data will be used to determine if sediments may serve as a reservoir where viruses can be concentrated and from which viruses can be injected by oysters. This project is being conducted jointly with the University of Southern Mississippi, Microbiology Department.

*Investigation of Photozone, A New Economical Disinfectant, to Maintain Suitable Water for Depuration of Oysters taken from Polluted Reefs* (Funded by BMR): Maintenance of water quality is a critical factor in successful operation of a closed-cycle oyster depuration system. This project is a study of the use of a disinfectant known as Photozone to determine if it can adequately control the microbial population in an oyster-holding tank, and otherwise improve the water quality without adversely affecting the ability of the oysters to pump and cleanse themselves.

*Development of Guidelines for Oyster Relaying on the Gulf Coast* (Funded by U.S. Food and Drug Administration): Studies are being conducted to determine the effect of temperature, salinity, and stress on the ability of oysters to eliminate indicator bacteria and enteroviruses. This information, along with existing published data and regulations, will be reviewed to develop new guidelines for oyster relaying. The University of Southern Mississippi has subcontracted the virus portion of the research.

*MICROSCOPY SECTION, Dr. William E. Hawkins, Head*

*Electron Microscopical Studies on the Effects of the Coccidium Eimeria funduli on Gulf Killifishes* (Funded by GCRL): Studies are being conducted on the inflammatory response and tissue alterations in livers of *Fundulus grandis* and *F. similis* during infection by the protozoan *Eimeria funduli*. The inflammatory response coincides with the appearance of sexual stages of the parasite and mainly involves monocytes, eosinophils, and heterophils. The parasite develops in a vacuole formed by host membranes. Connective tissue elements predominate in the latter phases of the host response. In higher vertebrates, the inflammatory response does not vary greatly among different species. It is hoped that detailed studies on model systems such as this will help identify mechanisms of combating infection and reacting to cell damage that are common to all fish. A manuscript is in preparation.

*The Response of Leucocytic Cells in the Hemopoietic Kidney of the Spot Leiostomus xanthurus and the Croaker Micropogonius undulatus to Damage by Cadmium* (Funded by GCRL): Previous studies have shown that cadmium damages proximal tubule cells in the spot kidney. Currently, other features of heavy metal poisoning in fish are being studied including the fate of damaged tubule cells and the effect of cadmium on leucocytes in the hemopoietic kidney of the spot and the croaker. After metal-induced damage, it appears that the tubules are infiltrated by a type of granular leucocyte; then, cell debris is removed by monocytes. These studies are part of a larger study on the effects of heavy metals on aquatic organisms including mechanisms of damage, tissue responses, and recovery from damage.

*Studies on Intracellular Parasites and Tissue Responses in Oysters* (Funded by GCRL and M-ASGP): These are continuing studies that originally began as a survey of Gulf coast oysters for submicroscopic inclusion bodies that harbor pathogenic microorganisms. The studies have been hampered by spring floods in 1978 and 1979 that killed many of the oysters in Mississippi Sound. To date no inclusion bodies have been found. Although the search for inclusion bodies is continuing, study emphasis has shifted because it became apparent that oysters from different locations had varying degrees of histological lesions, primarily foci of inflammatory cells. Light and electron microscopy are being employed to identify these changes in cells and tissues that might reflect a response to environmental factors. Attention has been focused on the hemocytes of the oyster because they are important in the inflammatory response and have been implicated in idiopathic hyperplastic diseases. A manuscript has been completed on the ultrastructure of oyster hemocytes with emphasis on organelle development and pathology.

*Histopathological Effects of Chlorine and Ammonia on the Mullet Mugil cephalus* (Funded by GCRL): Chlorine and ammonia are two possible pollutants associated with ocean thermal energy conversion (OTEC) plants. Histopathological studies have been initiated on the sublethal effects of these substances on mullet. The tissues studied include gill, kidney, liver, and small intestine. Light microscopic examination of plastic-embedded specimens has shown that acute chlorine exposure primarily damages gill lamellae and kidney glomeruli, secondarily. Small intestine and liver do not appear to be affected. Also, the ammonia exposures tested do not cause histopathological damage. These studies are aimed at identifying types and patterns of damage to aquatic organisms following sublethal exposures to toxic agents.

*Transmission and Scanning Electron Microscopic Study of the Kidney of the Atlantic Croaker Micropogonius undulatus* (Funded by GCRL): This is part of an ongoing study that hopefully will culminate in a histological and electron microscopical atlas of croaker cells and tissues. A manuscript on the ultrastructure of the croaker kidney was in preparation. The results of this study will provide a basis for determining pathological changes that might result from exposure to various toxicants and environmental factors.

*OYSTER BIOLOGY SECTION, Dr. Edwin W. Cake, Jr., Head*

*Oyster Depuration in Mississippi: Economic Assessments* (Funded by M-ASGP, GCRL, and University of Southern Mississippi): The third phase of a 3-year study was completed. The objective of this study was to estimate the economic feasibility of a proposed 96-bushel, pilot-scale, oyster depuration facility which might be operated on Biloxi Bay, Mississippi. The results of this study showed that the facility, as designed, would not be economically feasible at present prices and interest rates. Also, the present costs of natural cleansing are paid by state and private relaying operations. Alternate sizes and/or designs may be economically feasible.

*Enhancement of Oyster Production in a Tidal Lagoon in a U.S. Park Service Wilderness Area, Horn Island, MS* (Funded by GCRL): This study was conducted to provide the National Park Service with guidelines for improving and effectively managing oyster stocks in a tidal lagoon on Horn Island, a wilderness area. Significant sets of oyster spat occurred on oyster and clam shell cultch materials. Acceptable sets occurred on branches of the wax myrtle plant. The presence of brood oysters in experimental plots appeared to have no significant difference on spat set. Spat-plate samplers indicated the spat set was fairly uniform on all 40 experimental plots. Park Service officials will have to continue to place natural cultch materials in the lagoons of Horn Island, and to restrict the removal of large numbers of commercial-size oysters from those lagoons if the island's oyster stocks are to be adequate for consumption by island visitors.

*Population Dynamics of Selected Oyster Populations in Mississippi Sound and Adjacent Waters* (Funded by BMR and GCRL): This continuing oyster-monitoring program is assessing rates of spatfall, growth, natural and unnatural mortality, and the prevalence of oyster pathogens and predators on Mississippi major reefs. The results of this program are being used to assist the BMR with oyster management decisions such as when and where to plant cultch materials, and when to open various reefs for commercial harvesting and/or relaying.

*Development of an Oyster Management Model Applicable to the Mississippi Oyster Fishery* (Funded by BMR and GCRL): The Oyster Biology and Fisheries Management sections have acquired and are evaluating existing oyster production models for applicability to the Mississippi Sound oyster industry. Staff members are attempting to manipulate and/or modify models for this purpose. Data from the monitoring study (see previous project) will be utilized to operate the chosen model.

*Oyster Depuration in Mississippi: An Evaluation of Off-bottom Cleansing of Oysters* (Funded by GCRL): The second year of this study was significantly expanded from the utilization of single, plastic chicken coops to the use of a 48-tray (chicken-coop bottoms) rack for cleansing oysters from closed shellfish growing waters. The racks, coops, oysters, and transportation were supplied by the Cap'N Gollott Seafood Company of Biloxi. Laboratory personnel provided technical assistance as well as testing the oysters for confirmation of acceptable cleansing. The results of this cooperative, industry/laboratory study showed that acceptable levels of cleansing are obtained throughout the rack/tray system and within the prescribed 15-day cleansing period. Because of initial successes, the study is being upgraded to operational testing of several racks during various seasonal and environmental regimes.

*Field Investigations: U.S. Fish and Wildlife Service* (Funded by USF&WS): Section personnel conducted ecological field investigations of proposed projects that might impact the Mississippi coastal zone. The investigations enabled the USF&WS to assess U.S. Corps of Engineers permit applications for potential detrimental environmental impacts. This was the second year of a two-year project.

*PARASITOLOGY SECTION, Dr. Robin M. Overstreet, Head*

*Commercial Fishes of Mississippi: Spawning and Miscellaneous Biological Parameters* (Funded by NMFS and GCRL): The first of two tasks in this project was to determine the season of spawning, size of spawning fish, fecundity, and other aspects of reproduction for the spotted seatrout and red drum in Mississippi. The second task involved evaluating specific aspects of migration, feeding, growth, and health of a variety of commercial finfishes and shellfishes. This was the second year of a proposed three-year study.

*Digenea from Marine Fishes of the Northern Red Sea* (Funded by the Israel Academy of Sciences and Humanities): This long-term project will result ultimately in a monograph on piscine adult digeneans of Red Sea fishes for the *Fauna Palaestina* series. Many specimens already have been collected and more are expected within the next three years. Simultaneous work is also being conducted on other parasites of Israeli fishes, some of which have been implicated in diseases of humans who consume the fish and of fish that are reared commercially.

*Pathological Effects of Larval Thynnascaris Nematodes in the Rhesus Monkey (Macaca mulatta)* (Funded by the U.S. Air Force): This study was completed. Larval *Hysterothylacium* type MB from local foodfish quickly penetrated the stomach and anterior duodenum of the rhesus monkey, eliciting a host response characterized by mucosal hemorrhage and an initial abundance of eosinophils surrounding the worm. A man eating uncooked seafood containing high numbers of these larvae would probably be affected similarly.

*Studies of Parasites of the Northern Gulf of Mexico Region* (Funded by GCRL): Several studies are underway dealing with different parasitic organisms. These studies deal with the taxonomy, systematics, anatomy, life histories, pathological effects, and control of the organisms. Some of these parasites have been implicated in harm to commercial and recreational fishes. The organisms include microbes,

protozoans, metazoans, and even the hosts and potential hosts for the organisms.

*Macroinvertebrate Fauna of Mississippi and Alabama Coasts* (Funded by M-ASGP and GCRL): The two tasks in this project consist of (1) providing a manuscript for an illustrated guide to the macroinvertebrates from the northern Gulf of Mexico beaches, and (2) compiling a checklist and bibliography of estuarine and marine macroinvertebrates of coastal Mississippi and Alabama.

*Experimental Organism Culture Group* (Funded by GCRL): The culture-holding group of the Parasitology Section continued a part of its operation in a portion of the new toxicology building on the Laboratory's main campus. The purpose of this group is to develop techniques for culturing various freshwater and marine organisms, and to supply these organisms to GCRL sections and other state institutions for use in experiments, primarily toxicity testing and parasitological life-cycle studies.

Presently, several species of fishes, algae, copepods, mysids, amphipods, and other species are being reared year round. In addition to facilities in the toxicology building, other facilities include a cold culture lab, a hot culture lab, a large freshwater pond, and a fathead minnow rearing pond.

*Effluent Toxicity Evaluation* (Funded by First Chemical Corporation): This study was conducted in cooperation with the Microbiology Section.

*Development of Fate/Toxicity Screening Tests* (Funded by Battelle Memorial Institute): This study was conducted in cooperation with the Microbiology Section.

*Pollutant Transport in Mississippi Sound* (Funded by M-ASGP and GCRL): This study was conducted in cooperation with the Microbiology, Analytical and Environmental Chemistry sections.

***PHYSICAL OCEANOGRAPHY SECTION,***
***Charles K. Eleuterius, Head***

*Hydrographic-Climatic Atlas of Mississippi Sound* (Funded by M-ASGP and GCRL): Work continued on the production of the atlas. Information on the hydrography and meteorology of the area appears in various publications and in forms often not easy to comprehend. The atlas will provide a single source of up-to-date information on the hydrography and climate in a style for ease of understanding.

The development of such a reference volume required extensive statistical analysis of a large set of hydrographic data to determine characteristic seasonal levels and spatial distributions of physical-chemical parameters: pH, temperature, salinity, dissolved oxygen, and density. Statistical measures of central tendency (mean, median) and variability (range, coefficient of variability) of each parameter at four depths (surface, 5 feet, 10 feet, bottom) were depicted graphically via isopleth charts. Seasonal spatial distributions and variability of nitrite-nitrogen, nitrate-nitrogen, orthophosphate and total phosphate in surface waters were shown in the same manner as the other parameters.

Information on tides, hurricanes, bathymetry, river flows, wave climate, and geographical boundaries of Mississippi Sound was included in addition to the hydrographic parameters. Climatic information included shows typical weather patterns, air temperatures, photic period, and monthly wind velocity distributions.

*Hydrology of St. Louis Bay* (Funded by Du Pont): The analysis and report for the hydrographic baseline study of St. Louis Bay were completed. The objective was the determination of baseline hydrographic conditions using the parameters of water temperature, salinity, pH, dissolved oxygen, turbidity (depth of extinction of visible light), water color, and currents. These parameters were measured at sites in the bay and lower reaches of the rivers. In addition, automated sampling stations continuously recorded wind speed and direction, water elevations, water temperature, pH, dissolved oxygen, and salinity.

The findings of the study were included and discussed in a report that contained over 100 charts showing the spatial distribution of the hydrographic parameters. Composite charts showed the spatial distributions at 1-meter intervals throughout the water column. The empirical relationships between parameters were investigated and the results were included in both graphic and tabular form. Although the study was limited to only 13 months of data acquisition, it provided a comprehensive, first-order investigation of the hydrography of St. Louis Bay.

*Hydrodynamic-Numerical Circulation Model of St. Louis Bay* (Funded by Du Pont): The development of a forward-marching, finite-difference hydrodynamic-numerical model of St. Louis Bay, and the final report were completed. The model, based on the hydrodynamic equations of motion and continuity, allowed for the flooding and subsidence of waters from land areas. The tidal model accommodates wind stress and includes a quadratic form of bed resistance. A 30-second time step was used to provide the necessary spatial resolution to properly represent the basin geometry and current regime. A 29 x 39 uniform grid of topographic and bathymetric values was used to represent St. Louis Bay and adjacent land.

The model, tested initially using a simple sine wave as input, was later tested using prescribed tidal conditions. Lack of tidal measurements at the seaward boundary precluded the input of actual observed conditions for tidal forcing, thus the use of transformed values was employed to prove the proper functioning of the model. Current vector charts and tidal hydrographs were constructed from the model output. Computer programs were written to provide these computer-generated graphics.

The model is a useful tool for investigating the current regime in St. Louis Bay under various tide and wind

conditions. It provides a means of obtaining information on the fate and transport of materials that otherwise would be virtually impossible to obtain. The model can be expanded readily to a water quality model or transformed into a storm surge model.

*Spatial Data Management System* (Funded by the U.S. Corps of Engineers, Mobile District): To evaluate the impact of planned dredging activities upon the environment and to assess the cost/benefit ratio of such projects, the Corps of Engineers must analyze large amounts of various data in an accurate and efficient manner. The development of the spatial data management system entails the design and writing of a system of computer programs to handle, store, and retrieve large quantities of environmental, marine commerce, engineering, socio-economic, and archeological data. These data must be retrievable by a number of indexes. Programs must be developed that will display raw or processed data in a variety of graphic formats via cathode-ray tube (CRT) or hardcopy plotters.

Initial efforts began in March 1980 and involved the acquisition and review of existing programs, and the development of some of the program subroutines. Considerable effort has been devoted to the design of a viable system. The computer terminal, a Tektronix 4051, has been received but the telephone line to connect it with the remote computer has not been installed. The spatial data management system will be developed using a CDC 7600 at Boeing Computer Services, Renton, WA, on which the system will eventually reside. The system will take three years to complete.

*Characterization of Tidal Bayous and Development of Statistical Evaluation/Monitoring Techniques* (Funded by GCRL): This study involves an analysis of physical-chemical parameters recorded for tidal bayous along the Mississippi Gulf coast. The determination of system means and variability will provide a baseline for the respective bayou systems. The study is also providing information on the dynamics of these little-studied but important tidal bayous.

#### *PHYSIOLOGY SECTION, Dr. A. Venkataramiah, Head*

*Toxicity and Impingement-Entrainment Studies for Ocean Thermal Energy Conversion (OTEC) Plants* (Funded by U.S. Department of Energy): The purpose of this long-term project is to use laboratory bioassays to determine the potential effects of OTEC discharges on tropical marine fauna. The toxicants used in these tests are ammonia and chlorine; the test animals are mullet (*Mugil cephalus*), sargassum shrimp (*Latreutes fucorum*), sargassum fish (*Monocanthus hispidus*), and a copepod species.

In the second year (1979–80), acute bioassays (96 hours) were made by exposing mullet, sargassum shrimp, and sargassum fish initially to a wide concentration range of ammonia and chlorine. Acute bioassays with ammonia were made in a static system, and bioassays with chlorine were made in a flow-through seawater system. In subsequent acute bioassays, the animals were tested at closer intervals in narrower concentration ranges of ammonia and chlorine than the initial ranges by eliminating the extremely lethal levels. By repeating these bioassays several times the sublethal and incipient-lethal levels of ammonia and chlorine were established. The $LC_{50}$ and $LT_{50}$ values were also determined for each species. (In sublethal concentrations none of the animals die in a 96-hour test; in incipient-lethal levels part of the animals but not all of them will die.)

Mullet were tested later for chronic effects in the sublethal concentrations of ammonia and chlorine, by exposing the mullet to the so-called "harmless" doses of each toxicant for about 3 weeks. The survival and behavioral responses were monitored. Internal damage to the gills, kidney, and gut was determined using the electron microscopy techniques in collaboration with the Microscopy Section at GCRL.

A behavioral response pattern was developed from acute bioassays for each species which was different in ammonia and chlorine. Tolerance to these toxicants in the acute test was found to be size related. Larger mullet were more resistant to the toxicants than smaller ones, while in sargassum shrimp and sargassum fish it was the opposite way. Mullet taken from nearshore waters were more tolerant than the offshore sargassum species.

Chronic studies with sargassum shrimp and sargassum fish were begun. Bioassays with copepod species are scheduled for the third year of this contract.

#### *SYSTEMATIC ZOOLOGY SECTION, Mr. C. E. Dawson, Head*

*Systematic Studies on Fishes of the Families Microdesmidae, Dactyloscopidae, and Syngnathidae* (Funded by GCRL): A report on the family Microdesmidae for the UNESCO publication *Check-list of Fishes of the Eastern Tropical Atlantic (CLOFETA)* was completed, and a similar report on the family Syngnathidae is in preparation.

A manuscript reviewing the western Atlantic sand stargazers (Dactyloscopidae), including 17 species in 7 genera, was completed.

The manuscript treating the family Syngnathidae for the Sears Foundation series *Fishes of the Western North Atlantic* was completed.

Current studies include work leading to review of the gastrophorine estuarine or freshwater pipefishes, synopses of African and Australian pipefish faunas, and a review of the genus *Micrognathus*.

## SPECIAL FACILITIES

#### *MARINE EDUCATION CENTER, Mr. Gerald C. Corcoran, Curator*

Visits to the Center decreased from 32,754 to 21,182 this year. Several factors are responsible for this decline, such as increased gasoline prices, cancellation of all field trips by several local school systems, and a decreased MEC budget which did not allow any changes in the displays. The largest decrease was in the area of "local public" who

usually visit the Center several times a year to view new animals and new displays.

Two special classes in marine science were taught to 26 students from Sacred Heart Girls High School. The students were exposed to the study of local plants and animals, and to identification of marine vertebrates and invertebrates.

The in-service program for teachers continued with the offering of a new course titled "Marine Science for Elementary Teachers." During the course, teachers developed units of instruction on marine life which included film strips, slide programs, identification using colored photographs, coloring books, and games. When a sufficient number of these units have been developed, they will be consolidated by grade level and distributed to local school systems. The first class had 10 students.

The volunteer summer program had four students this year. They assisted in the care and feeding of the exhibited animals, and thus were informally introduced to the identification of local fishes.

The Creative Learning in Unusual Environments (CLUE) groups took advantage of the Center programs again this year with six groups, a total of 170 students, attending. A similar group of 61 students from Jonesboro, Arkansas, also visited the Center. As in past years staff supervised day and night seining trips, a boat tour of Biloxi Harbor, a visit to Marine Life in Gulfport, and the regular Center program.

Since January 1980, Center staff have been involved in producing a quarterly booklet for the Coastal Heritage Awareness Program. Funded by the Mississippi-Alabama Sea Grant Consortium and the Gulf Coast Research Laboratory, the program involves local teachers and students in providing information gathered from local residents on the historical aspects of coastal living. One booklet has been published and two more are being compiled for distribution at the beginning of the 1980–81 school year.

Personnel acted as a clearinghouse for information on a Manatee which was sighted along the coast during the winter of 1979. Search efforts were coordinated between the U.S. Fish and Wildlife Service, Gainesville, FL, and New Orleans, LA. The state Bureau of Fisheries and Wildlife (formerly Game and Fish Commission), Jackson, MS, was kept informed. Although the animal was not captured, its appearance served to initiate a local network to assure minimum response time to such appearances in the future.

At the request of the Biloxi Library, the Center took part in their Children's Hour program on three occasions by showing a film on snakes and allowing the children a "hands-on" experience with several live specimens from the MEC display. A short talk was given advising children to avoid all unfamiliar snakes.

A workshop was conducted for the Sea Grant Advisory Service-sponsored program to publicize the "Year of the Coast," a nationwide effort to acquaint people with resources of the sea. The correct procedure for seining was demonstrated, and participants were shown techniques used to identify local marine animals.

A new "Fun Book" was developed similar to one published last year. The booklet features local marine animals and gives hints on their normal coloration. Children at elementary grade levels thus learn body shapes, markings, and coloration of many of the local animals.

*THE GUNTER LIBRARY, Mr. Malcolm S. Ware, Senior Librarian*

Standing orders for serial and journal publications were reduced to 221 by eliminating no longer needed titles, and three new subscriptions were purchased.

The interlibrary loan/photocopy program filled requests for 263 reprints this year involving 109 loan transactions for various research projects. There were 176 requests for loans from other libraries.

A total of 102 new books were purchased. Through exchanges and donations, 352 reprints were received and filed.

Recent involvement in networking and consortia include membership in the International Association of Marine Science Libraries and Information Centers, the Gulf Coast Biomedical Library Consortium, and the new Coastal Mississippi Library Cooperative. These affiliations have given considerable depth to the literature acquisitions program, and hold promise for future financial support from both federal and state sources.

Library attendance increased this year from 70 to 85 individuals per day.

*ICHTHYOLOGY RESEARCH MUSEUM, Mr. C. E. Dawson, Head*

Two hundred and forty-three lots of fishes, primarily syngnathids and dactyloscopids, were added to the ichthyological collection. These included gifts of important research materials from Australia, the Philippine Islands, New Caledonia and other Indo-Pacific localities. Exchanges, loans, and identifications of specimens were provided for a number of investigators and museums in North America, Europe, and elsewhere.

*WATER ANALYSIS LABORATORY, Dr. Thomas F. Lytle, Head*

The Analytical and Environmental Chemistry sections have conducted many of the analyses for a comprehensive pollutant transport study through the Water Analysis Laboratory. Other sections and research groups at the Laboratory taking advantage of the Water Lab services were: Toxicology, Microbiology, anadromous, Office of Fisheries Assistance, Ecology, and Oceanography. Analyses were provided for several graduate students at GCRL to assist in their research. In addition, analyses were performed under contract to the South Mississippi Planning and Development District, and the Arkansas Valley Dredging Co. (for the city of Biloxi). Personnel of the Water Lab served as instructors for the course Marine Chemistry (1980), in some aspects of oceanographic laboratory analysis. Most analysis requests were for water, but sediment, shrimp waste, and fish food also were analyzed.

The tasks performed during 1979–80 included analyses for: orthophosphate, total phosphorus, nitrate, nitrite, ammonia (now reported as un-ionized ammonia), silicate, sulfate, pH, chloride, hardness, turbidity, suspended solids, residual chlorine, alkalinity, calcium, Kjeldahl nitrogen, phenols, silver, copper, potassium, manganese, magnesium, iron, and zinc.

*COMPUTER SECTION, Mr. Gerald Strength, Head*

The total number of jobs processed through the computer center was 2,172 with a total run time of 1027.36 hours. This decrease in utilization from the previous year is due primarily to the winding down of the Du Pont project, and to the limitations caused by the small interval memory (16k) of the present computer. This core size limitation becomes more acute as the sizes of data bases expand and sizes of the programs to handle these larger data bases also expand. Sections contributing largely to the job/hour total were: Finance (303/244.43), Oceanography (345/150.17), Fisheries (236/110.81), Microbiology (128/31.11), with the remaining jobs and hours contributed to the other sections.

A pilot study has been initiated with the objective of determining the computer needs of the Laboratory over the next 10 to 12 years, and recommending the most cost-effective method of meeting those needs.

*PUBLIC INFORMATION/PUBLICATIONS SECTION, Miss Catherine Campbell, Head*

In August 1979, the Section staff resumed producing the Laboratory's weekly radio program "On Course," which is devoted to news and interviews concerned primarily with aspects of marine science research and education. A five-minute format was adopted, and by the end of July 1980, fifty new programs had been produced, dubbed and distributed. Programs were recorded on the main campus in Ocean Springs. They are regularly aired over seven regional radio stations: WGCM, Gulfport, 1230 AM, 9:35 p.m. Sunday; WGUD, Moss Point, 106 FM, 11:25 a.m. Thursday; WLOX, Biloxi, 1490 AM, 8:25 a.m. Sunday; WOSM, Ocean Springs, 103.1 FM, 5:55 p.m. Saturday; WPMP, Pascagoula, 1580 AM, 1:35 p.m. Wednesday; WRPM, Poplarville, 108 FM, 10:30 a.m. Tuesday; and WXGR, Bay St. Louis, 1190 AM, 9 a.m. Sunday.

As part of the Laboratory's internal communications, the staff began an informal, photocopied weekly news sheet called "Lab Samplings," which is issued each Friday. Items used pertain to official comunications, GCRL-sponsored activities, participation by staff members in outside activities related to their work, visitors, and the Laboratory's governing board.

During the fall of 1979 and spring of 1980, work progressed on updating a Laboratory informational slide program with new color slides and a new taped narrative. In the spring, another slide program was developed entitled "The Estuary: An Important Natural Resource," which is being used to call attention to the numerous and diverse benefits derived from estuaries.

During the fall of 1979, section personnel completed Volume 6, Number 3 of the Laboratory's technical journal *Gulf Research Reports*. Printing specifications were written, bids received, and a contract awarded; finished copies were received in mid-February and approximately 770 copies were mailed by the section staff.

Work began in January on Volume 6, Number 4. Manuscripts already reviewed, revised, and accepted by the editor were copy edited by the staff for style, consistent usage and other details, then masters were typed in page format for printing. By the end of June, 32 pages had been set.

Earlier deadlines for the submission of manuscripts were adopted by the editorial staff, effective in 1981, as follows: manuscripts exceeding 10 pages should be submitted by April 1, those 10 pages and under by July 1.

During the 1979–80 fiscal year, the staff produced 12 monthly issues of the Laboratory newsletter *Marine Briefs*, completing the eighth and beginning the ninth year of the publication. Articles were written or edited by the staff, and masters typed for the newsletter layouts, which included one 4-page, seven 6-page, and four 8-page editions. The newsletter was printed outside the Laboratory. Approximately 3900 copies were distributed regularly by hand and by mail.

The Section provided Laboratory participation in the exhibits for the annual meeting of the Mississippi Academy of Sciences, held in Biloxi in March, and in the Coast Day '80 program, held in May at Phillips College in Gulfport.

Through news releases and photographs generated by the staff, and by arranging for members of the scientific staff to do radio and television programs, the Section helped provide timely information to the public. In the case of such newsworthy events as the occurrence of the red tide organism, reported for the first time in Mississippi waters, news releases were made to the media almost daily. Staff members assisted news media persons in obtaining interviews and stories throughout the year.

During the past year, more than 80 news releases were disseminated to about 50 selected daily and weekly newspapers, television and radio stations, wire services and special correspondents. In addition, approximately 100 photos of small groups of field trip and summer college students were sent to hometown and campus publications throughout the nation.

To inform students at campuses affiliated with GCRL concerning summer courses offered at the Laboratory, special articles were sent to campus publications, and a radio interview with the Registrar was taped and sent to on- and off-campus radio stations.

Programs were provided by the staff for civic clubs, and members of the technical staff were obtained to speak to civic clubs and to serve as judges for science fairs. Tours of Lab facilities and informational/educational programs were

conducted for more than a dozen high school, college, and other groups.

## ACADEMIC PROGRAM

### *NEW AFFILIATE*

Belmont College in Nashville, Tennessee, affiliated with the Laboratory during the year. The number of out-of-state affiliates is now 40.

### *SUMMER SESSION, Dr. David W. Cook, Registrar*

The 1979 summer academic session involved 71 students registering individually for a total of 101 student courses. Twenty-nine students registered through Mississippi schools, 35 through out-of-state affiliates, and seven through non-affiliated out-of-state institutions. Courses taught during the 1979 summer session and the instructors were:

- Introduction to Marine Zoology, Dr. Buena Ballard, Southwestern Oklahoma State University
- Marine Vertebrate Zoology and Ichthyology, Dr. J. William Cliburn, University of Southern Mississippi
- Marine Invertebrate Zoology, Dr. Edwin W. Cake, Jr., staff
- Marine Aquaculture, Dr. Edwin W. Cake, Jr., staff
- Marine Ecology, Drs. James T. McBee and Robert A. Woodmansee, staff
- Marine Botany, Dr. R. B. Channell, Vanderbuilt University
- Physical Marine Geology, Dr. Ervin Otvos, staff
- Introduction to Behavior and Neurobiology of Marine Animals, Dr. Leo S. Demski, University of Kentucky
- Special Problems in Marine Science, staff

During the 1979–80 academic year, 10 students earned credit in the course Marine Science for Elementary Teachers, offered at night at the Marine Education Center located in Biloxi. This course was taught by Mr. Gerald C. Corcoran, staff.

### *GRADUATE RESEARCH PROGRAM*

Courses offered in the Graduate Research Program during this period included: Seminar, Special Problems in Marine Science, Special Topics in Marine Science, and Graduate Research in Marine Science. A total of 71 semester hours credit were earned by graduate research students during the year.

Three new students were accepted into this program during the year, and five students completed their degrees. At the end of the year, 11 students in the program were candidates for the master's degree, and seven were candidates for the doctorate.

Each candidate's name, thesis title, degree sought, and home university are listed below according to the senior staff member directing their work:

*Dr. Edwin W. Cake, Jr.:*

David H. Barnes, "Polychaetes associated with an artificial reef in the north central Gulf of Mexico," M.S., University of Southern Mississippi.

David A. Blei, "A successional study of the hydrozoans inhabiting an artificial reef in the north central Gulf of Mexico," M.S., University of Southern Mississippi.

Alfred P. Chestnut, "Distribution, population dynamics and reproductive biology of the burrowing clam, *Diplothyra smithii* Tyron," Ph.D. degree awarded 1980, University of Southern Mississippi.

William W. Falls, "Food habits and feeding selectivity of larval striped bass, *Morone saxatilis* (Walbaum), under intensive culture," Ph.D., University of Southern Mississippi.

Kenneth Hase, "Enhancement of oyster production in a tidal lagoon in a U.S. Park Service wilderness area," M.S., University of Southern Mississippi.

Roger A. Jennings, "Seasonality and community structure of benthic macroinvertebrates in a riverine estuary," M.S., University of Southern Mississippi.

Katherine A. McGraw, "Growth and survival of hatchery-reared and wild seed oysters in Mississippi Sound and adjacent waters," Ph.D. degree awarded 1980, University of Washington.

John E. Supan, "A comparison of 'off-bottom' relaying of oysters in the Mississippi Sound," M.S., University of Southern Mississippi.

*Mr. J. Y. Christmas, Jr.:*

James R. Warren, "Changes in the population of the juvenile groundfish, *Micropogonius undulatus, Leiostomus xanthurus* and *Cynoscion arenarius,* from Mississippi Sound before and after the opening of the 1979 shrimp season," M.S., University of Southern Mississippi.

*Dr. Lionel N. Eleuterius:*

James C. Garrison, "Some relationships of salt marsh vegetation to abundance of the marsh periwinkle *Littorina irrorata* Say," M.S. degree awarded 1980, University of Mississippi.

Stephen H. Sky-Peck, "A study of growth and nitrogen content of *Spartina alterniflora* and *Juncus roemerianus* in response to source and concentration of nitrogen," M.S. degree awarded 1979, University of Mississippi.

*Dr. Thomas D. McIlwain:*

Barbara J. Crowe, "Contribution to the life history of the Southern Kingfish, *Menticirrhus americanus* (Linnaeus) in Mississippi," M.S., University of Mississippi.

Frederick E. Schultz, "Description and comparison of the eggs, larvae, and young of the yellow bass, *Morone mississippiensis*, with striped bass, *Morone saxatilis*, white perch, *Morone americanus*, and white bass, *Morone chrysops*," M.S., University of Mississippi.

*Dr. Robin Overstreet:*

Thomas L. Deardorff, "Adult ascaridoid nematodes from fishes of the northern Gulf of Mexico with notes on some larval forms," Ph.D., University of Southern Mississippi.

Tom E. Mattis, "Larval development of two trypanorhynch tapeworms from Mississippi Sound," Ph.D.,

University of Southern Mississippi.

Mobashir Ahmad Solangi, "Pathological changes in some estuarine fish exposed to crude oil and its water-soluble fractions," Ph.D., University of Southern Mississippi.

*Dr. A. Venkataramiah:*

Ann L. Gannam, "Effects of various proportions of animal and plant protein supplemented with methionine on the growth and survival of the Penaeid shrimp, *Penaeus aztecus* Ives," M.S. degree awarded 1980, University of Southern Mississippi.

Shiao Yu Wang, "Studies on the effect of declining oxygen tension on the respiratory rate of brown shrimp, *Penaeus aztecus* Ives in relation to temperature and size," M.S., University of Southern Mississippi.

*Dr. Robert Woodmansee:*

Zoghlul Kabir, "Relationship between the diurnal vertical migration and egg development in planktonic copepods in Mississippi Sound and adjacent northern Gulf of Mexico waters," Ph.D., University of Mississippi.

John P. Steen, "Factors influencing the spatial and temporal distribution of selected crustacean plankton species in Davis Bayou," Ph.D., University of Mississippi.

Michael C. Torjusen, "The distribution, abundance and feeding habits of larval and juvenile bothid flatfishes of Mississippi Sound and adjacent waters," M.S., University of Mississippi.

#### *SCIENTIFIC FIELD TRIP PROGRAM*

As an adjunct to the teaching program, each year the Laboratory provides living accommodations, classroom laboratories, and essential services to visiting scientific field trip groups made up of college and university students and their professors. Such groups may stay for periods of up to several weeks, live in the dormitory, use Laboratory boats to make collections of marine life from the sea and from the beaches of offshore islands, and study their specimens in the classroom laboratories. During the year the Laboratory was visited by 32 field trip groups. The total number of people involved were 475 professors and students who stayed an average length of 3.0 days. Some came as far as 2,000 miles to study the marine life of the Gulf of Mexico.

### SPECIAL AND COMMUNITY SERVICES

#### *FISHERY ASSISTANCE*

*The Biloxi Schooner–A Seafood Industry Newsletter* (Funded by GCRL): The second volume of this monthly publication was printed. Its readership is currently 95, consisting primarily of Mississippi seafood packers and processors, although it is also sent to industry-associated persons in eight other states.

*Seafood Plant Wastewater Sampling Program* (Funded by GCRL): Fisheries assistance service personnel carry out a weekly sampling service which provides seafood plant owners with data on the pollutant levels of five components of their processing wastewater. Regulations concerning permissible levels are established by the EPA and enforced by the state Bureau of Pollution Control. Advisory services are offered to plant management to help in controlling pollutants.

During the year, 106 visits were made to seafood plants, and 154 hours were spent in collecting 211 samples of wastewater at the plants; the time required to process the samples in the laboratory was 243.5 hours.

A 3-month quality control sampling program was conducted in seafood plants for the Microbiology Section. Two plants were visited on a weekly basis. Bacteria samples were taken with a commercial sampling device and cultured on a prepared packaged medium. Results gave plant owners a general picture of the extent of a bacterial contamination in their plants and on the products.

A 2-month intensive sampling program was conducted at three seafood plants to collect data on the levels of ammonia in their wastewater discharges. This was in response to a proposed rule by the EPA that would classify ammonia as a toxic substance, thus subjecting the plants to severe limitations. These data were tabulated and a three-page letter of comment was sent to the EPA.

An oyster quality sampling program was conducted during the winter months at one plant which was buying large amounts of shucked oysters from Virginia. On the delivery day, all gallon containers would be sampled for their pH reading. There is a good correlation between low pH and poor oyster quality. Because shipments were being checked, the number of poor-quality gallons shipped was reduced.

A "Special Notice" reviewing old and proposed wastewater regulations was written, printed, and distributed to seafood plants. This was done during a period of increased activity on the part of EPA regulatory personnel.

Throughout the year many requests were received by the office for information of all types. These requests came from industry, universities, state agencies in Mississippi and other states, and foundations. The majority of industry requests were for information on processing and packaging equipment that could be used in their operations, and new methods for better preparing standard products. Several small experiments were conducted in the plants in connection with product handling and packaging problems.

*Seafood Sanitation Program* (Funded by GCRL): At the request of processors, the Microbiology Section makes plant inspections and collects samples for bacteriological testing to determine any problem areas. Suggestions are made for correcting any deficiences noted in plant sanitation practices.

During the fiscal year, 24 visits were made to processing plants, and 273 crabmeat samples were analyzed at the request of industry. Each sample was analyzed for aerobic plate count, coliform and fecal coliform counts, and *Escherichia coli* count.

"Sanitation Notebook for the Seafood Industry," a booklet developed jointly by GCRL, Virginia Polytechnic Institute, and the National Fisheries Institute, was completed. Copies have been distributed to 20 seafood processors in the state.

*ENVIRONMENTAL AFFAIRS*

The Environmental Affairs Committee is composed of all senior scientific staff members and is coordinated by the Ecology Section. The committee provided an interdisciplinary approach to environmental problems in the wetlands and estuaries of Mississippi, primarily as a service to the state's Bureau of Marine Resources. However, the committee also cooperates with other state and federal agencies on special projects that are not under the direct jurisdiction of the BMR. The majority of this work deals with the review of permit requests for work proposed in the wetlands and estuaries. Committee members made comments and recommendations on permit requests. In most cases a site visit was made by representatives of the committee.

*PUBLIC SEMINARS*

The Gulf Coast Research Laboratory hosts a series of staff seminars throughout the year. These seminars are open to the public and speakers include invited scientists as well as officials from various levels of local, state and federal government. The central purpose of the seminars is to promote better dissemination, understanding, and use of scientific information at all levels of society. Seminars presented during fiscal year 1980 were as follows:

*"Boat and Water Safety,"* by Ms. Trudy Mills, U.S. Coast Guard Auxiliary, Flotilla 38, July 17, 1979.

*"Immune Mechanisms in Cold-Blooded Animals,"* by Dr. L. William Clem, Chairman, Department of Microbiology, University of Mississippi Medical Center, August 14, 1979.

*"Radiation and Its Biological Implication,"* by Dr. Kenneth N. Vanek, Medical Radiation Physicist, Keesler Air Force Base, September 11, 1979.

*"Propagation of the American Alligator,"* by Mr. William W. Falls, Fisheries Research and Development Section, Gulf Coast Research Laboratory, September 25, 1979.

*"A Biofouling Intensity Study in the Gulf of Mexico,"* by Ms. Brenda J. Little, Biologist, Naval Oceanographic Research and Development Activity, National Space Technology Laboratories, October 9, 1979.

*"History of Gulf Coast Research Laboratory–Part I,"* by Dr. Gordon Gunter, Director Emeritus, Gulf Coast Research Laboratory, October 23, 1979.

*"Emergency Medical Satellite Communications,"* by Dr. William Brundage, Director, Office of Research, University of Southern Mississippi, November 13, 1979.

*"Mariculture in India,"* by Dr. E. G. Silas, Director, Central Marine Fisheries Research Institute, Cochin, India, November 21, 1979.

*"Genitalia Development in the Shrimp, Penaeus indicus H. Milne Edwards 1837 from Sundarban Estuary, Bangladesh,"* by Mr. Zoghlul Kabir, Ecology Section, Gulf Coast Research Laboratory, December 11, 1979.

*"Evolution of the Isthmus of Panama and Adjacent Areas,"* by Mr. Allen Lowrie, Oceanographer, Naval Oceanographic Office, National Space Technology Laboratories, December 18, 1979.

*"Resource Utilization in Fisheries,"* by Dr. Steve Ross, Associate Professor of Biology, University of Southern Mississippi, January 8, 1980.

*"Marine Turtle Research on the Atlantic Coast of Florida,"* by Dr. Llewellyn Erhardt, Barnett Professor of Environmental Science, University of Central Florida, February 12, 1980.

*"Morphology of Tadpole Tails and their Evolutionary Significance,"* by Dr. Otto Sokol, Assistant Professor, Department of Anatomy, University of South Alabama Medical School, March 11, 1980.

*"Barrier Island Formation–Gulf Coast,"* by Dr. Ervin Otvos, Head, Geology Section, Gulf Coast Research Laboratory, April 8, 1980.

*"Development and Applications of an Airborne Low Light Level Sensor for Marine Fisheries Research,"* by Mr. Charles M. Roithmayr, Fishery Research Biologist, National Marine Fisheries Service, May 13, 1980.

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